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Effect of taping and its conditions on electromyographic responses of knee extensor muscles

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ABSTRACT

Introduction: The present study investigated the effect of stretchable characteristics of elastic therapeutic tape and its elongation on surface electromyography (EMG) of knee extensor muscles during knee extension movements.
Methods: Nine healthy men performed knee extension movement with the application of normal elastic tape or highly stretchable tape and without the tapes (control). Tapes were applied on the anterior thigh to cross the knee joint with no elongation and elongation of 50 and 75% of the maximum stretchability. Surface EMG was recorded from the vastus lateralis (VL) muscle and proximal (RFp) and distal (RFd) sites of the rectus femoris muscle.
Results: Under the no-elongation conditions, decreases in the surface EMG amplitude of the VL and RFd muscles were observed with normal tape during the isometric contraction phase and with highly stretchable tape during isometric and eccentric contraction phases, compared with the control ($p < 0.05$). There were no significant differences in surface EMG among the different elongation conditions in any muscles ($p > 0.05$).
Discussion: These results suggest that the stretchable characteristics of tapes change the effect of elastic tape application on neuromuscular activation of the applied muscles and these effects are not dependent on the elongation of the tape.

1. Introduction

Elastic therapeutic taping such as Kinesiology taping has been widely used in sports activity and/or daily living life for the purpose of supporting muscles and/or joints (Williams, Whatman, Hume, & Sheerin, 2012). While improvements in physical performance facilitated by the elastic therapeutic tapes have been reported (Choi & Lee, 2018; Fratocchi et al., 2013; Trecroci, Formenti, Rossi, Esposito, & Alberti, 2017), the physiological and biomechanical mechanisms are not fully understood. One of the physiological mechanisms involves the modulation of proprioception. Macgregor, Gerlach, Mellor, and Hodges (2005) showed that patella taping-induced skin stretch increased motor unit activation of the knee extensor muscle (Macgregor et al., 2005). Konishi (2013) demonstrated that a decrease in maximal voluntary contraction (MVC) and electromyography (EMG) induced by tendon vibration was inhibited by the application of Kinesiology taping (Konishi, 2013). These studies suggested that cutaneous stimulation by the application of tape to skin enhances neuromuscular activation and physical performance. On the other hand, it is considered that the application of taping across a joint mechanically or physically supports the muscular or joint force production. Although the effect of tape application on MVC has been investigated in some muscles, contraction modes, and shape of tapes, the results show discrepancy and the discrepancy in the results were not associated with muscle groups and/or contraction modes. (Csapo & Alegre, 2015). Since a

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stretched tape applied across a joint physically acts to pull two segments, the stretchable characteristics of tape and condition of elongation when tape is applied would play a key role in understanding the mechanical or physical mechanism behind the effect of tape application on physical performance. In fact, a positive effect of tape application on MVC was observed on using tape stretched to 75% of its maximum stretchability (Fratocchi et al., 2013). In athletic and/or rehabilitation fields, users or trainers can control and choose the % elongation when tapes are applying. Testing the effect of elongation degree on physical performance would provide useful information when elastic therapeutic tape is used.

Recent studies demonstrated regional neuromuscular activation within muscles: upper trapezius (Holtermann et al., 2009), rectus femoris (RF) (Watanabe, Kouzaki, & Moritani, 2012), and gastrocnemius (Vieira, Windhorst, & Merletti, 2010). We demonstrated non-uniform neuromuscular activation along the RF muscle during voluntary contractions (Watanabe et al., 2012), electrical nerve stimulation (Watanabe, Kouzaki, Ando, Akima, & Moritani, 2015), and the spinal reflex (Watanabe, 2018), and suggested that proximal and middle/distal sites of the RF muscle are independently regulated by the central nervous system. However, the effect of the modulation of proprioception of a joint and/or peripheral muscle on regional regulation of the RF muscle is unclear.

The purpose of the present study was to investigate the effect of the stretchable characteristics of tape and its elongation on neuromuscular activation of knee extensor muscles. We hypothesized that neuromuscular activation of the knee extensor muscles is influenced by stretchable characteristics and elongation degree of tape across the knee joint due to the mechanical or physical support provided by the tape to facilitate extension of the knee joint. Also, we hypothesized that neuromuscular activation of the distal sites of the RF muscle is selectively influenced by tape application to the knee joint, since the proximal and middle sites of the RF muscle preferentially activate hip flexion and knee extension, respectively (Watanabe et al., 2012). To test these hypotheses, surface EMG of the vastus lateralis (VL) muscle and proximal and distal sites of the RF muscle during knee extension movements were compared among conditions using tapes with different stretchable characteristics and degrees of elongation.

2. Methods

2.1. Subjects

Nine healthy men (age: 22.2 ± 4.5 years, height: 172.7 ± 6.0 cm, body mass: 63.6 ± 10.1 kg) volunteered for this study. All subjects were healthy, with no history of any musculoskeletal or neurological disorders. All procedures were conducted in accordance with the Declaration of Helsinki and approved by the Research Ethics Committee for Human Experimentation at Chukyo University (No. 2017-003). The subjects gave informed consent for the study after receiving a detailed explanation of the purposes, potential benefits, and risks associated with participation.

2.2. Experimental design

The subjects sat in a dynamometer and their hip joint angles were fixed at 110° (inner angles) during the experiment. Subjects performed leg extension movement. This task was composed of 4 s of extending the knee joint from 90° to 170° with concentric contraction, 2 s of holding the knee joint angle at 170° with isometric contraction, and 4 s of flexing the knee joint angle from 170° to 90° with eccentric contraction (Fig. 1). Target and actual knee joint angles were shown to the subjects on a monitor. Five trials were performed with an inter-trial test of 10 s as a condition.

This study tested different type of tapes: normal (Kinelogy EX, Nitoms Inc., Tokyo, Japan) and highly stretchable (custom ordered, Nitoms Inc., Tokyo, Japan) tapes, and degree of its elongation on neuromuscular activation. Tension of normal and highly stretchable tapes was measured by a tensiometer (AUTO GRAPH AG-IS, Shimazu Corporation, Kyoto, Japan) with a 300 mm/min elongation speed at 23 C° and 50% room humidity. Maximum lengths of elongation were approximately 70 and 120 mm for normal and highly stretchable tapes, respectively, and the maximum tension was approximately 60 N for both.

Seven different conditions were employed: a) without tape as control (CT), b) normal tape without elongation (N0), c) normal tape with elongation at 50% of maximum (N50), d) normal tape with elongation at 75% of maximum (N75), e) highly stretchable tape without elongation (S0), 6) highly stretchable tape with elongation at 50% of maximum (S50), and 7) highly stretchable tape with elongation at 75% of maximum (S75). The tape was placed over the knee joint from the proximal edge of the tibia to anterior superior iliac spine with (N50, N75, S50, and S75) and without (N0 and S0) stretch when the knee joint angle was at 90°. Subjects

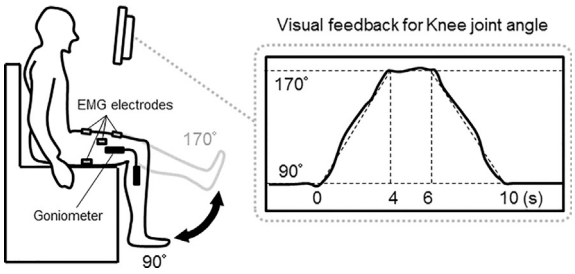

Fig. 1. Experimental setting for knee extension movement with visual feedback on the knee joint angle EMG, electromyography.

underwent a control condition (CON) as the first trial and the other six conditions in random order with 1–2 min of rest. For N0 and S0 conditions, length of tape was set at distance between the anterior superior iliac spine and tibial tuberosity for each subject. For N50 and S50 conditions and N75 and S75 conditions, 50 and 75% of the tape length used for N0 and S0 conditions were applied, respectively.

2.3. Surface electromyography

Surface electromyogram signals were recorded from the VL muscle, proximal (RFp) and distal (RFd) sites of the RF muscle, and biceps femoris (BF) muscle. Electrode locations for the VL and BF muscles were at the mid point of the muscle. For the RF muscle, electrodes for RFp and RFd were located at 20 and 50% along a line between the anterior superior iliac spine and superior edge of the patella from the proximal site. Since our previous studies demonstrated different surface EMG responses between the proximal and middle/distal sites of the RF muscle (Watanabe et al., 2012), the present study recorded surface EMG from two different sites along the longitudinal axis of the RF muscle. Active electrodes with a 0.1 × 1.0 cm silver bar detection area (FA-DL-141, 4 assist, Tokyo, Japan) were used. Surface EMG was sampled at 2000 Hz and recorded by an A-D converter (Power Lab 16/35, AD Instruments, Melbourne, Australia) with the data generated by an electro-goniometer at the knee joint (FA-DL-210, 4 assist, Tokyo, Japan). Recorded surface EMG signals were filtered with an 8th order Bessel bandpass filter at 10–450 Hz and full-wave rectified. Since the electrode locations for the RF muscle were on the line between the anterior superior iliac spine and tibial tuberosity, a part of applied tape covers the electrodes for the RF muscle.

We separated the range of the knee joint angle into seven phases: 95–115° (CON1), 115–145° (CON2), and 145–165° (CON3) of the concentric contraction phase, isometric contraction phase (> 165°) (ISO), and 165–145° (ECC1), 145–115° (ECC2), and 115–95° (ECC3) of the eccentric contraction phase. For each phase, the rectified amplitude of surface EMG was averaged across three of five trials for each condition and electrodes. Three of five trials were selected by visual inspection to assess whether target and performed knee joint angles matched without a large error. Averaged rectified surface EMG for each condition and each phase was normalized by the value of CON for each muscle and subject.

2.4. Statistics

To test the effect of taping and its stretchable characteristics, the Wilcoxon rank sum test was used to compare the normalized surface EMG amplitude for the pairs of CT and N0, CT and S0, and N0 and S0. To test the effect of % elongation, the normalized surface EMG amplitude of N0, N50, and N75, and S0, S50, and S75 was tested by the Friedmann test and Wilcoxon rank sum test was applied when significant effect of % elongation was found with the Friedmann test. Since this study used multiple comparisons, the level of significance was modified by Bonferroni correction (the modified level of significance was 0.05/the numbers of comparisons for each analysis). Therefore, the level of significance in the Wilcoxon rank sum test was set at 0.016 (0.05/3). Statistical analysis was performed using SPSS (version 15.0, SPSS, Tokyo, Japan) and MATLAB (R2015b, MathWorks GK, Tokyo, Japan).

3. Results

For the VL muscle, the normalized surface EMG amplitude of CT was significantly higher than N0 at ISO ($p = 0.015$) and S0 at ISO ($p = 0.015$), ECC2 ($p = 0.011$), and ECC3 ($p = 0.015$) (Fig. 2). For RFd, the normalized surface EMG amplitude of CT was significantly higher than N0 at ECC1 ($p = 0.015$) and S0 at ISO ($p = 0.008$) and ECC1 ($p = 0.015$) (Fig. 2). There were no significant differences in normalized surface EMG amplitudes among CT, N0, and S0 for the RFp or BF muscle ($p > 0.016$) (Fig. 2).

No significant effects of % elongation on normalized surface EMG amplitude were found for normal (Fig. 3) or highly stretchable (Fig. 4) tapes in all tested muscles ($p > 0.016$).

4. Discussion

The present study investigated the effect of stretchable characteristics of tape and its % elongation on surface EMG of knee extensor muscles during knee extension movements. We found that application of normal and highly stretchable elastic therapeutic tapes changes neuromuscular activation of knee extensor muscles. While the effect of normal tape was shown only in the isometric phase, the effect of highly stretchable tape was observed in both isometric and eccentric contraction phases (Fig. 2). This means that the effect of the application of elastic therapeutic tapes on neuromuscular activation is influenced by the stretchable characteristics. On the other hand, no effect of elongation degree of tapes was noted in surface EMG (Figs. 3 and 4). The results support the hypothesis that neuromuscular activation of the knee extensor muscles is influenced by stretchable characteristics, but not the hypothesis that neuromuscular activation of the knee extensor muscles is influenced by elongation degree of tape. Also, there were different results in surface EMG between proximal and distal sites of the RF muscle. The effect of tape application was observed at the distal site of the RF muscle, but not at its proximal site (Fig. 2). The results support the hypothesis of this study that neuromuscular activation of the distal sites of the RF muscle is selectively influenced by the application of tape to the knee joint.

Since sample size of the present study was not large, power analysis was performed for all compared data pairs (Vincent, 2005). Mean power was 83.2 ± 15.0%. It can be confirmed that the statistical analysis in this study was adequate, because a power of 80% is considered suitable for correct analysis (Vincent, 2005).

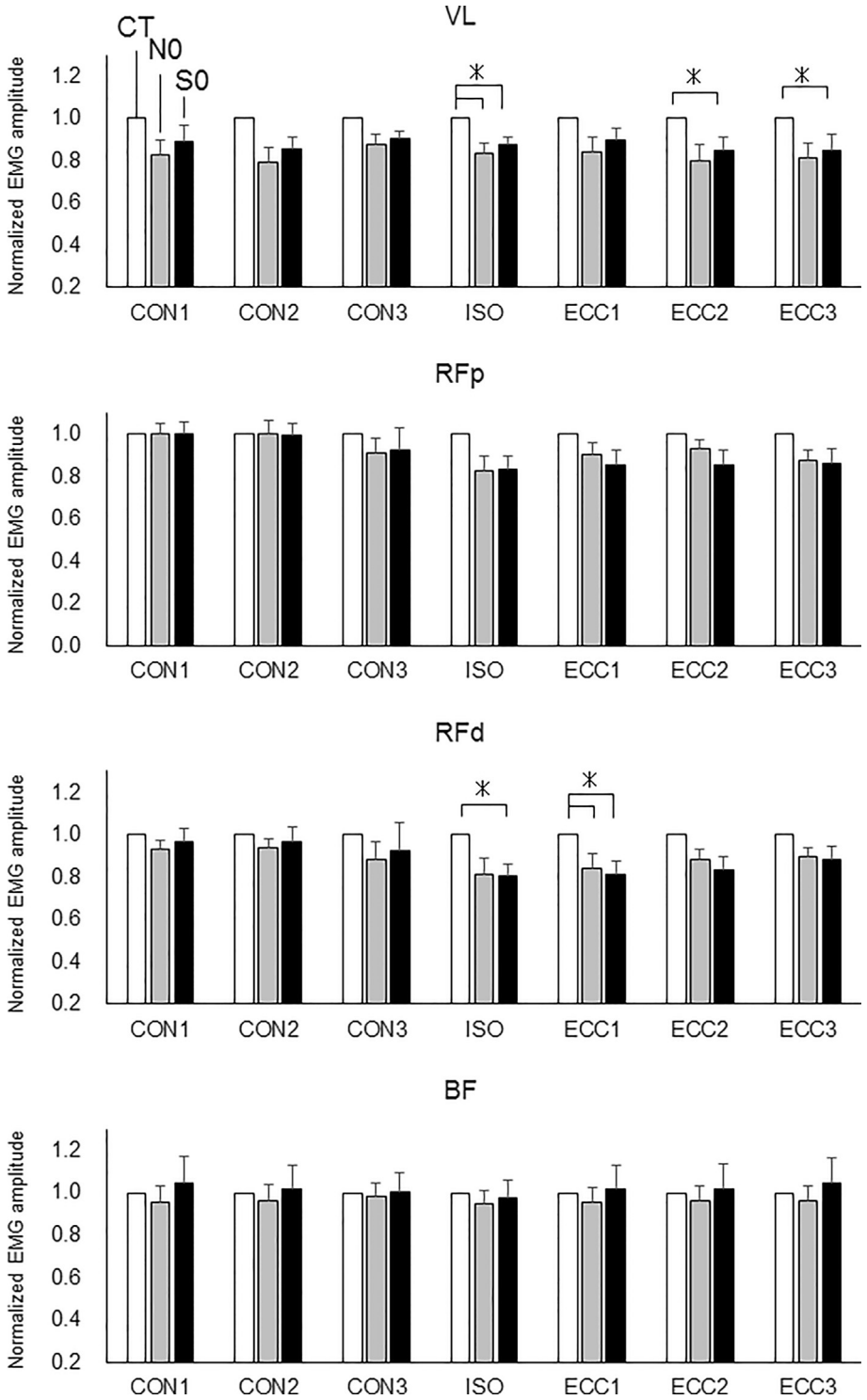

Fig. 2. Mean surface electromyography amplitude for control (CT), normal tape (N0), and highly stretchable tape (S0) for the vastus lateralis (VL) muscle, proximal (RFp) and distal (RFd) sites of the rectus femoris muscle, and biceps femoris (BF) muscle. CON1, concentric contraction from 95 to 115° of knee joint angle; CON2, concentric contraction from 115 to 145° of knee joint angle; CON3, concentric contraction from 145 to 165° of knee joint angle; ISO, isometric contraction around 165° of knee joint angle; ECC1, eccentric contraction from 165 to 145° of knee joint angle; ECC2, eccentric contraction from 145 to 115° of knee joint angle; ECC3, eccentric contraction from 115 to 95° of knee joint angle. * $p < 0.05$ between conditions.

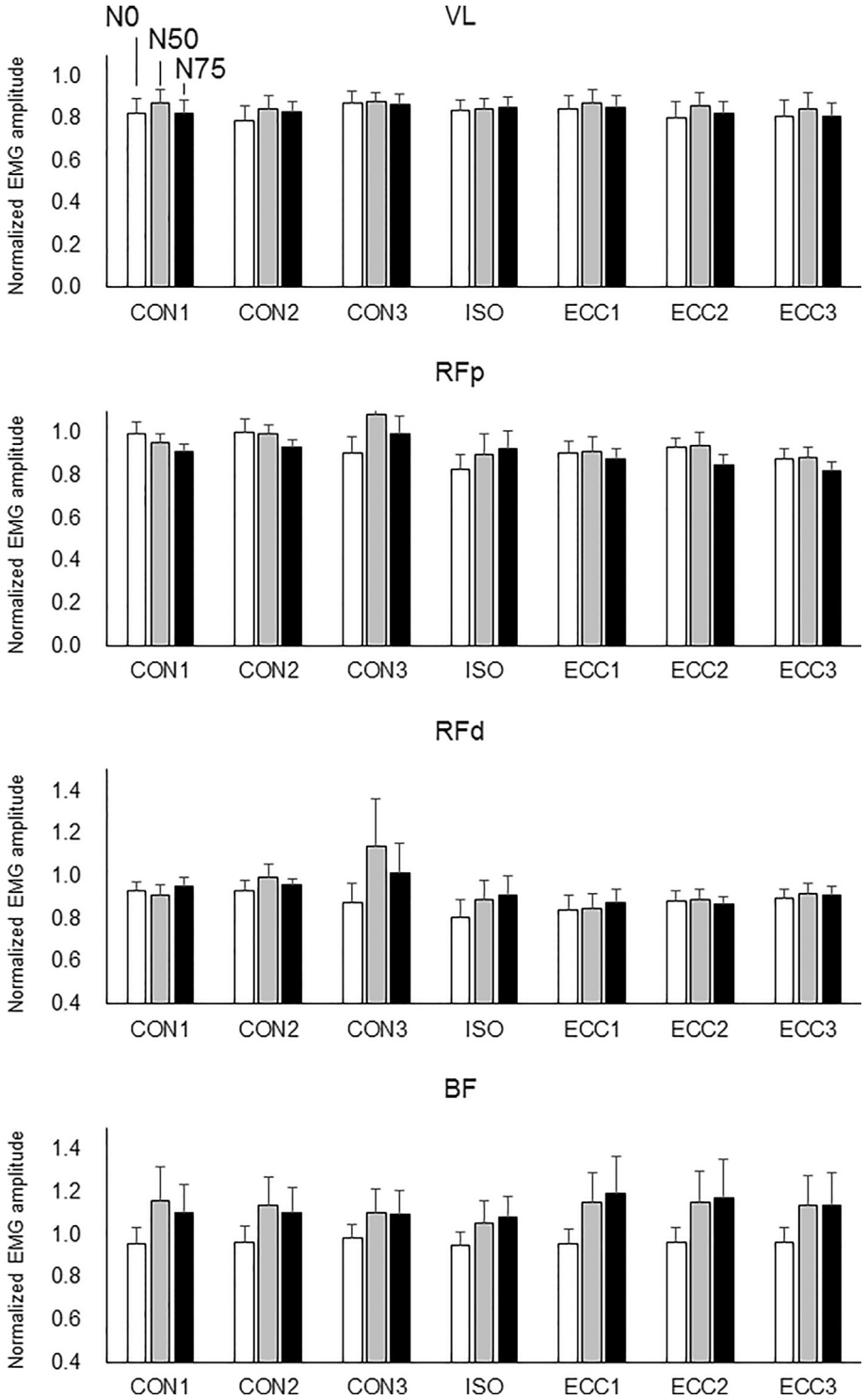

Fig. 3. Mean surface electromyography amplitude for normal tape with no elongation (N0) and with elongation of 50% (N50) and 75% (N75) of maximum tape length for the vastus lateralis (VL) muscle, proximal (RFp) and distal (RFd) sites of the rectus femoris muscle, and biceps femoris (BF) muscle. CON1, concentric contraction from 95 to 115° of knee joint angle; CON2, concentric contraction from 115 to 145° of knee joint angle; CON3, concentric contraction from 145 to 165° of knee joint angle; ISO, isometric contraction around 165° of knee joint angle; ECC1, eccentric contraction from 165 to 145° of knee joint angle; ECC2, eccentric contraction from 145 to 115° of knee joint angle; ECC3, eccentric contraction from 115 to 95° of knee joint angle.

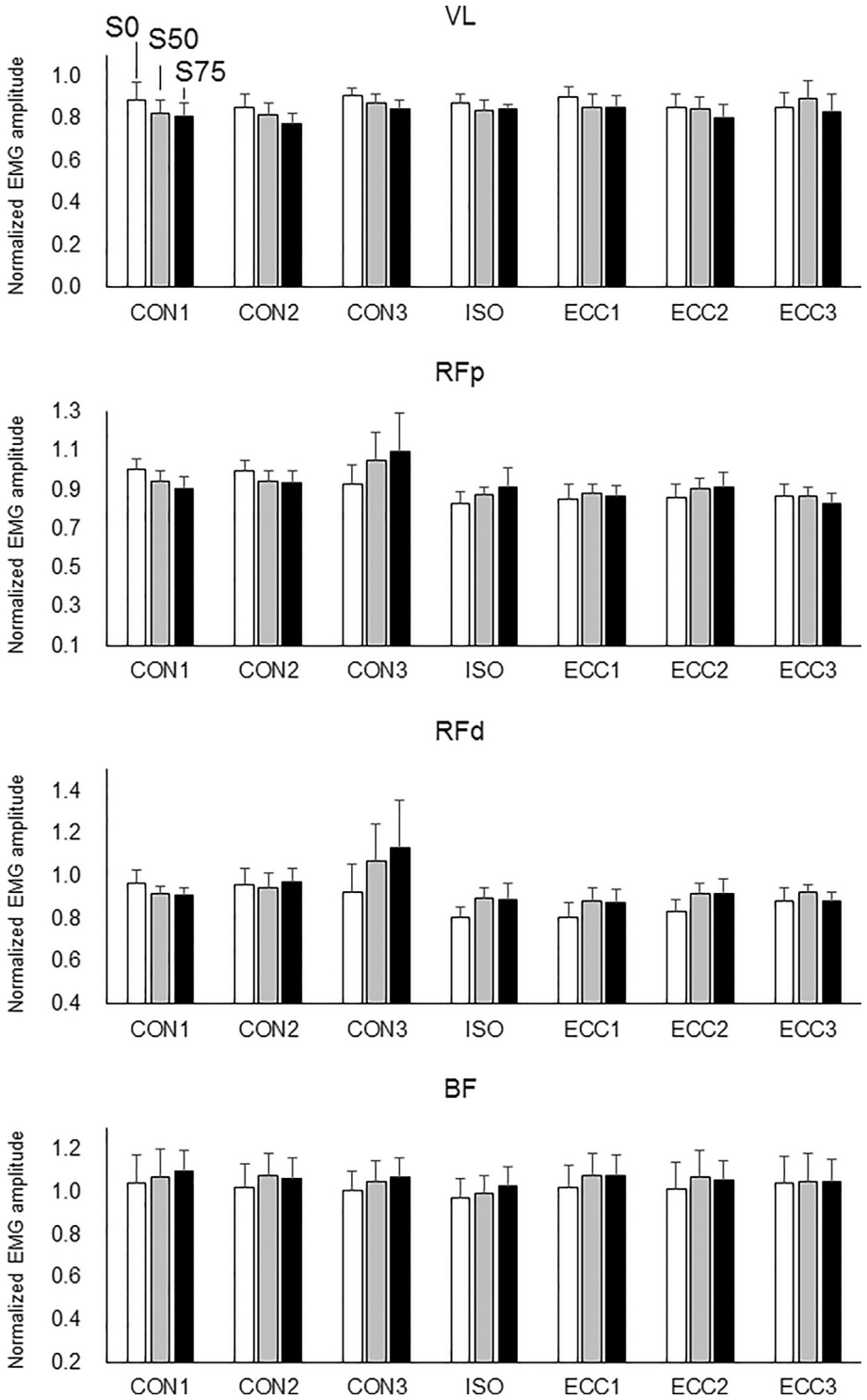

Fig. 4. Mean surface electromyography amplitude for highly stretchable tape with no elongation (S0) and with elongation of 50% (S50) and 75% (S75) of maximum tape length for the vastus lateralis (VL) muscle, proximal (RFp) and distal (RFd) sites of the rectus femoris muscle, and biceps femoris (BF) muscle. CON1, concentric contraction from 95 to 115° of knee joint angle; CON2, concentric contraction from 115 to 145° of knee joint angle; CON3, concentric contraction from 145 to 165° of knee joint angle; ISO, isometric contraction around 165° of knee joint angle; ECC1, eccentric contraction from 165 to 145° of knee joint angle; ECC2, eccentric contraction from 145 to 115° of knee joint angle; ECC3, eccentric contraction from 115 to 95° of knee joint angle.

4.1. Effect of application of tape and its stretchable characteristics

When the elastic therapeutic tapes were applied to the knee joint angle, surface EMG amplitudes of the VL and RFd muscles were significantly lower than under the control condition in some phases during knee extension movements (Fig. 2). Since the subjects performed the same tasks with a constant load, i.e., weight of lower leg, among the conditions, decreases in surface EMG of agonistic muscles means that lower neuromuscular activation was needed to perform the same load task. For knee extensor muscles, Aktas and Baltaci (2011) and Kim and Lee (2013) demonstrated increases in maximal joint torque by the application of elastic therapeutic tapes (Aktas & Baltaci, 2011; Kim & Lee, 2013). Although the present study used submaximal contraction at a low force level, the results of the present study could be supported by the results of these previous studies (Aktas & Baltaci, 2011; Kim & Lee, 2013). These positive effects of elastic tape application could be explained by traction force between edges of the applied tape. It should be noted that significant effects of tape application on surface EMG of the VL and RFd muscles were observed in isometric and eccentric contraction phases, but not during concentric contraction (Fig. 2). In previous studies, increases in maximal isokinetic joint torque were shown during both concentric and eccentric contractions (Aktas & Baltaci, 2011; Kim & Lee, 2013). The present study suggests that effect of elastic therapeutic tape application on submaximal contraction would depend on the contraction mode.

The present study used two types of therapeutic tape with different stretchable characteristics. This is the first study to test the effect of stretchable characteristics of elastic tape on neuromuscular activation. There were different phase-dependent responses between normal and highly stretchable tapes when tape elongation was absent. For the VL muscle, while a significant difference in surface EMG amplitude with CT was found only in the isometric contraction phase (ISO) with normal tape (N0), that with highly stretchable tape (S0) was significantly lower than CT in isometric (ISO) and eccentric (ECC2 and ECC3) contraction phases (Fig. 2). Although it would be difficult to discuss its mechanism, these results suggest that the effect of the application of elastic tape on neuromuscular activation is influenced by stretchable characteristics of tape.

4.2. Effect of an elongation degree of tape

Since traction force is generated between edges of the applied tape on the skin, degree of its elongation could be a factor influencing the tape's effect on physical performance. While most studies applied elastic tape at its original length, Fratocchi et al. (2013) used tape with traction corresponding to approximately 75% of the tape's potential elasticity, and showed positive effect of Kinesio Taping on isokinetic elbow peak torque (Fratocchi et al., 2013). However, no studies have investigated the effect of elongation degree of elastic tape. The present study tested three different conditions: no elongation and elongation of 50 and 75% of maximum stretchability, using two types of tape. The results showed no significant effects of elongation on surface EMG amplitude in any thigh muscles ($p > 0.05$) (Figs. 2–4). This means that the effect of application of elastic tape on neuromuscular activation is not influenced by elongation degree of tape. Based on the positive effect found on the application of tape in N0 and S0 when compared with CT (Fig. 2), this positive effect could be provided in various elongation degree. These results suggest that practitioners such as trainers and/or therapists don't need undue attention to elongation degree for applying the elastic tape.

4.3. Region-specific neuromuscular responses in rectus femoris muscle

Regional neuromuscular activation along the RF muscle was noted during voluntary contractions: isometric contraction, walking, and climbing the stairs (Watanabe et al., 2012; Watanabe, Kouzaki, & Moritani, 2014, 2017), in our previous studies. Also, our previous studies showed non-uniform neuromuscular responses between the proximal and distal sites within the RF muscle during electrical nerve stimulation (Watanabe et al., 2015) and tendon reflex (Watanabe, 2018). These findings suggest that neuromuscular activation of distal sites of the RF muscle is independently regulated in both central and peripheral nervous systems. In the present study, a significant decrease in surface EMG amplitude by application of the elastic tape was noted at the distal site of the RF muscle, but not at the proximal site (Fig. 2). This means that the application of the elastic tape selectively altered the neuromuscular activation at the distal sites of the RF muscle. The decrease in surface EMG amplitude by tape application could be due to the support of knee extension joint torque production by traction force and stimulation of proprioceptors via cutaneous tissues of the thigh. The present study suggests that extrinsic factors such as application of the elastic tape can also modulate regional neuromuscular activation of the RF muscle. From this result, the application of elastic tape to a joint may not alter torque production at neighboring joints via bi-articular muscles.

4.4. Conclusion

The present study tested the effect of stretchable characteristics in elastic therapeutic tape and its elongation on surface EMG of knee extensor muscles during knee extension movements. The application of the tape decreased neuromuscular activation of the knee extensor muscles. Highly-stretchable tape has a different effect on neuromuscular activation of the knee extensor muscles when compared with normal stretchable tape. Elongation degree of the tapes doesn't change the effect of the application of the elastic tape on neuromuscular activation of the knee extensor muscles. We conclude that application of the elastic tape can promote joint torque production, the stretchable characteristics change the effect of elastic tape application on neuromuscular activation of the applied muscle, and these effects are not dependent on elongation degree of the tape.

Ethical publication statement

Our protocol was approved by the Committee for Human Experimentation of the Chukyo University.

We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines

Disclosure of conflicts of interest

None of authors has any conflicts of interest to disclose.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.humov.2018.12.003.

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