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Activities of Upper Limb Muscles Related to the Direction of Elastic Tape Application in Healthy Adults: A Randomized Trial of Parallel-Aligned Versus Cross-Aligned Tape Application

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Abstract

The purpose of this study was to evaluate the differences in electromyographic (EMG) activities of upper limb muscles between cross- and parallel-aligned taping and to compare the effects of these 2 taping methods in healthy adults. Thirty subjects, who volunteered for this study, were tested under 3 taping conditions in random order: (1) no taping, (2) cross-aligned taping, and (3) parallel-aligned taping. EMG activities of the biceps brachii, triceps brachii, flexor carpi ulnaris, and extensor carpi radialis muscles were measured. All muscles showed significant differences in EMG activity among the 3 conditions ($p<.05$). In the post hoc test, biceps brachii and triceps brachii muscles showed significant differences in EMG activity between the no taping and the cross-aligned taping conditions and between the no taping and the parallel-aligned taping conditions. Additionally, the EMG activities of the flexor carpi radialis and extensor carpi radialis muscles appeared to be significantly different between the no taping and parallel-aligned taping conditions. These findings demonstrate that taping may be helpful for decreasing muscle activity, regardless of the direction of tape application. This study provides useful information to future researchers regarding the effects of taping on muscle activity.

Key Words : Application direction; Muscle Activity; Taping; Upper limb.

Introduction

Upper limb (UL) function is very important for the performance of the activities of daily living, and in some cases, functional recovery of the ULs during rehabilitation of various disorders requires extensive intervention. In patients presenting with functional deficits of the ULs, decreased neuromuscular control is frequently related to pain and motor dysfunction causing changes in the movement patterns (Buckle and Devereux, 2002). Repetition of abnormal movement results in problems in sensory-motor processes and sequential task performance strategies, which may be altered in a wide range of conditions (Haudum et al, 2012).

In general, a variety of techniques, including therapeutic massage, myofascial release, range of motion exercises, stretching and strengthening exercises, physical modalities, neurophysiological approach, forced use therapy, and task-oriented approach, have been used in the field of rehabilitation for improvement of UL function. Technique selection depends on the therapeutic aim and the clinician's decision-making process (Oujamaa et al, 2009), although previous studies have failed to establish clinical evidence for the superiority of any particular technique (Mostafavifar et al, 2012). The lack of evidence makes adoption of effective therapeutic approaches for patients with functional impairments of the UL difficult for most clinicians (Mostafavifar et al, 2012). In particular, this often results in greater problems in restoring functional impairments in chronic conditions

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as these require rehabilitation for a prolonged period.

Traditionally, elastic taping has been used to facilitate neuromuscular control and support the therapeutic effects of rehabilitation (Williams et al, 2012). Its application may be relative to the skin condition, with a longitudinally elongating range of about 40% of its original length (Kisner and Colby, 2007). The elasticity of the tape provides a pulling force during application, allowing widening of the soft tissue space and lifting of the fascia (Morris et al, 2013). Taping has been widely known to enhance muscle strength, balance, coordination, flexibility, and mobility as well as to reduce edema and pain (Bell and Muller, 2013; Morris et al, 2013; Kaya et al, 2011). Furthermore, taping has been suggested to be an effective method for the inhibition of muscle imbalance and optimization of muscular efforts during daily routine activities, which is probably essential during various rehabilitation strategies for decreasing functional deficits (Williams et al, 2012). It has also been reported to improve force production in the muscle, thereby increasing muscle contractility (Lin et al., 2011). In some situations, the direction of the tape application influences muscle activity; that is, the parallel arrangement along muscle fibers facilitates their activity, while the cross alignment suppresses it (Tobin and Robinson, 2000). However, previous studies have failed to provide evidence for the inhibitory effects of cross-aligned taping of the fibers on muscle tone and even found that parallel-aligned taping, along the skin and overlying the fibers, reduced motor neuron excitability (Chang et al, 2010; Cormie et al, 2011; Firth et al, 2010). Description of muscular responses to tape application is not consistent, as it remains unclear whether the direction of tape application is a factor in its effect on the underlying muscles.

Taping was originally developed by many researchers and clinicians as a novel component of the treatment for improving UL function (Kaya et al, 2011; Williams et al, 2012), and has attained widespread acceptance for symptomatic management of various conditions in the clinical setting (Mostafavifar et al, 2012; Williams et al, 2012). However, to the best of our knowledge, despite the clinical benefits of various methods of taping, little attention has been paid to clarification of the differences in the effects of the different application methods, during the study efforts for the basic taping procedure. Therefore, this study aimed to determine whether the EMG activities of the UL muscles differ between the cross- and parallel-aligned taping of muscle fibers, and to compare the effects of these 2 methods. We postulated that parallel-aligned taping facilitates EMG activity of the muscle and cross-aligned taping inhibits it.

Methods

Subjects

Thirty healthy subjects (age: 23.8±2.1 years, height: 170.3±8.5 ㎝, weight: 64.0±11.4 ㎏, 20 males, 10 females) were recruited from a university. The inclusion criteria for the subjects were as follows: (1) no sensory problems, (2) no limitation of motion of the UL joints, (3) no neurological or musculoskeletal impairments such as paralysis, contractures of the limbs, and pain, and (4) no psychological disorders. Prior to study participation, all subjects were provided with a detailed description of the experimental procedures and their safety, and were required to sign a written consent form.

Surface electromyographic recording

The surface EMG system (Laxtha, Laxtha Inc., Daejeon, Korea), which comprised 8 electrodes, an analog to digital converter with 16-bit resolution, a universal serial bus connection, and a WEMG-8-type cable, was used to assess muscle activity for the biceps brachii, triceps brachii, flexor carpi radialis, and extensor carpi radialis muscles. We prepared the skin of each participant to reduce skin impedance by dry shaving the hair with a disposable razor, abrading the skin with fine sandpaper, and cleansing the skin with an alcohol swab. After the skin was dry, pairs of circular Ag/AgCl surface electrodes with a contact diameter of 11 ㎜ were placed on standard locations, as suggested by Cram et al (1998), with an inter-electrode distance of 20 ㎜. The electrode placement for the biceps brachii muscle was approximately at the dorsal center of 90° flexion over the elbow joint. For the triceps brachii muscle, it was halfway between the acromion and elbow joint on the ventral aspect of the upper arm. For the flexor carpi radialis muscle, it was placed on the proximal third point of volar aspect in forearm supination. For the extensor carpi radialis muscle, it was placed on the dorsal aspect of the forearm, 5 ㎝ distal to the lateral epicondyle in forearm pronation.

We determined the dominant UL for each participant by observing the limb with which each participant grabbed a pen. Telescan 2.89 software (Laxtha, Laxtha Inc., Daejeon, Korea) was used to acquire EMG signals at a sampling frequency of 1024 ㎐ and to process them with a 60 Hz notch filter and 20-500 ㎐ bandpass filter. To normalize the EMG signals recorded for each muscle, the root mean square (RMS) of a 5-sec maximal voluntary isometric contraction (MVIC) was calculated for each muscle at the manual muscle testing positions recommended by Hislop and Montgomery (2007), and expressed as a percentage of the calculated RMS of the %MVIC.

Procedures

Subjects were tested under the following 3 taping conditions on each of the muscles, biceps brachii, triceps brachii, flexor carpi radialis, and extensor carpi radialis, in random order: (1) no taping, (2) cross-aligned taping along each muscle, and (3) parallel-aligned taping. To determine the application order of each condition, randomization was carried out with the conventional randomization directory process in which a random number board was used to produce one card for each subject, by a person who was not involved in the assessment process of the subjects. The guidelines for taping of each muscle were consistent with the protocol suggested by Morris et al (2013). For taping, standard tape (Kinesiology taping, 3NS, Seoul, Korea) with a diameter of 5 ㎝ was applied on the dominant UL for all applications across the 3 taping conditions. The tape length for the cross- and parallel-aligned tapings was adjusted for the circumference of the application regions and the interval between the origin and insertion points of each muscle, respectively. The middle portion of the tape was opened for placement of the electrodes.

EMG data of each muscle were collected with the subjects sitting on a fixed chair with hip and knee joints flexed to 90°, elbow flexed to 90°, and wrist in neutral position. The EMG measurement for the biceps brachii muscle was performed with the shoulder abducted to 15°, elbow flexed to 90°, and forearm in full supination. For measuring the activity of the triceps brachii muscle, the UL was positioned with shoulder flexed to 170°, elbow flexed to 90°, and forearm in neutral position. The EMG measurement for the flexor carpi radialis muscle was performed with the shoulder abducted to 15°, elbow flexed to 90°, forearm in full supination, and wrist flexed to 10°. For measuring the activity of the extensor carpi radialis muscle, the UL was positioned with shoulder flexed to 15°, elbow flexed to 90°, forearm pronated, and wrist extended to 10°. An isometric contraction of the UL was then performed by holding a 2-㎏ dumbbell for 5-sec (Vandervoort et al, 1987) (Figure 1). EMG data was averaged over 3 trials with a 1-min rest interval.

Statistical analysis

All the data were analyzed using the SPSS ver. 12.0 software. Descriptive statistics was used to assess the general characteristics of subjects. One-way repeated ANOVA was used to examine muscle activity changes among the 3 taping conditions in the biceps brachii, triceps brachii, flexor carpi radialis,

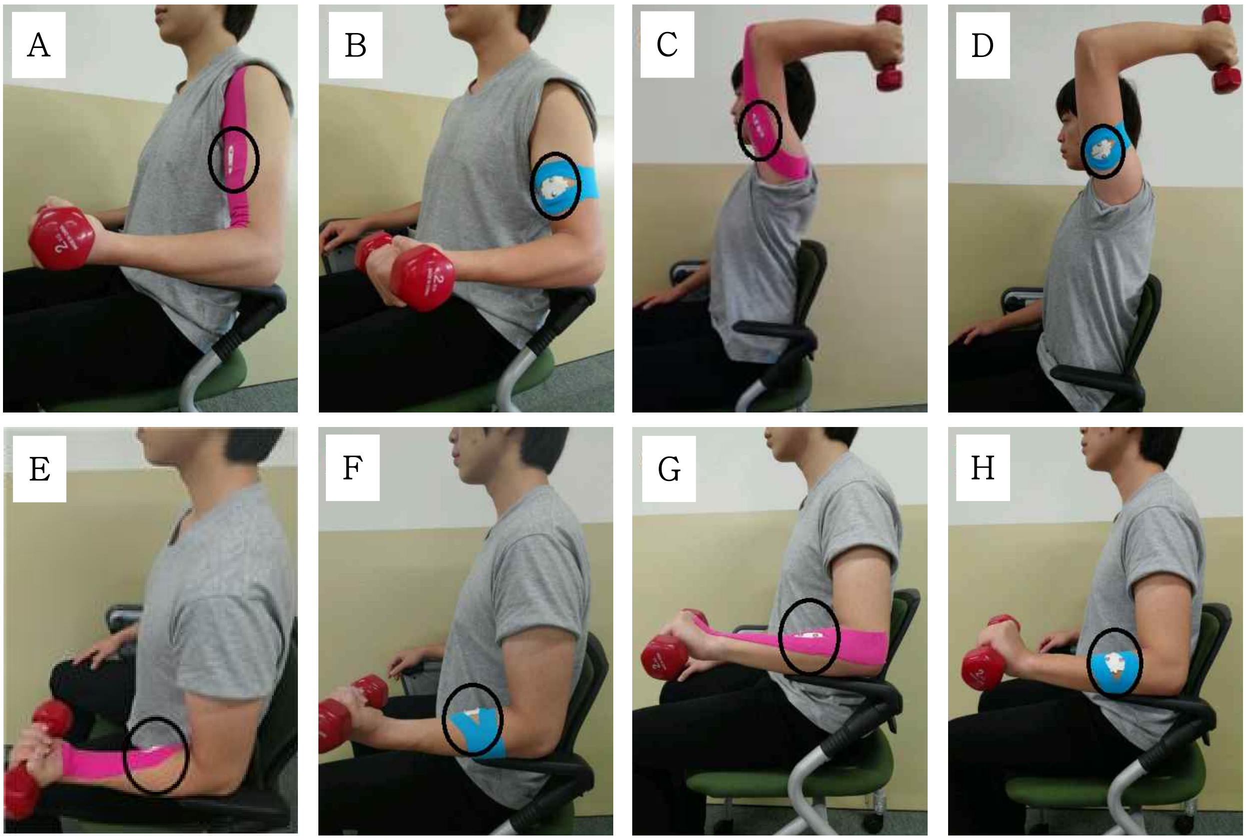

Figure 1. Experimental conditions for the EMG measurements of each muscle (A: parallel-aligned taping for the biceps brachii muscle, B: cross-aligned taping for the biceps brachii muscle, C: parallel-aligned taping for the triceps brachii muscle, D: cross-aligned taping for the triceps brachii muscle, E: Parallel-aligned taping for the flexor carpi radialis muscle, F: cross-aligned taping for the flexor carpi radialis muscle, G: parallel-aligned taping for the extensor carpi radialis muscle, H: cross-aligned taping for the extensor carpi radialis muscle.

and extensor carpi radialis muscles. When the p-value was <.05, the Bonferroni adjustments were used-for post hoc pairwise comparisons. Statistical significance was set at .05.

Results

Table 1 summarizes the EMG data of each muscle during the 3 taping conditions. The EMG activities of all muscles appeared to be significantly different among the 3 taping conditions (no taping, cross-aligned taping, and parallel-aligned taping) ($p<.05$).

In the biceps brachii muscle, post hoc test revealed a significant difference between the no taping and the cross-aligned taping conditions ($p<.001$) and between the no taping and the parallel-aligned taping conditions ($p=.001$), but there was no significant difference between the cross-aligned taping and the parallel-aligned taping conditions ($p=.246$). In the triceps brachii muscle, post hoc test revealed a significant difference between the no taping and the cross-aligned taping conditions ($p=.049$) and between the no taping and the parallel-aligned taping conditions ($p=.012$), but no significant difference between the cross-aligned taping and the parallel-aligned taping conditions ($p=.832$). In the flexor carpi radialis muscle, post hoc test revealed a significant difference between the no taping and the parallel-aligned taping

Table 1. Comparison of the EMG activity of each muscle during the 3 taping conditions (Unit: %MVIC, N=30)

Muscle	No taping	Cross-aligned taping	Parallel-aligned taping	F
Biceps brachii	17.86±9.15[a]	15.78±7.83	14.95±6.18	13.92*
Triceps brachii	20.03±6.83	17.89±7.75	17.24±8.20	4.71*
Flexor carpi radialis	20.98±14.67	19.11±13.47	16.57±11.68	5.95*
Extensor carpi radialis	33.89±13.21	32.81±12.89	31.08±13.30	5.96*

[a]mean±standard deviation, *p<.05.

conditions (p=.004), but no significant difference between the no taping and the cross-aligned taping conditions (p=.235) and between the cross-aligned taping and the parallel-aligned taping conditions (p=.121). In extensor carpi radialis muscle, post hoc test revealed a significant difference between the no taping and the parallel-aligned taping condition (p=.021), but no significant difference between the no taping and the cross-aligned taping conditions (p=1.000) and between the cross-aligned taping and the parallel-aligned taping conditions (p=.154).

Discussion

Rehabilitation for functional impairments, which involves improving the performance of activities of daily living and thereby enhancing the quality of life, requires appropriate UL movement patterns. Taping has been widely adopted by clinicians for the optimization of UL function. Although studies to support the therapeutic benefits of taping in the management of symptoms of musculoskeletal disorders have been conducted previously (Mostafavifar et al, 2012), differences in muscle activity with different taping application directions have not been sufficiently investigated yet. Therefore, this study was designed to identify changes in the EMG activities of the UL muscles after cross-aligned and parallel-aligned tapings, and to compare the effects of these 2 methods. Our findings suggested that taping may be used favorably to reduce muscle activity; however, we did not find any significant differences between the 2 directions of tape application.

In this study, EMG measurements were performed with the UL in a static position during an isometric contraction while holding a specific weight. This method has been acceptable for most clinicians, as performing measurements in a dynamic state, which may be considered more functional, requires special devices to control the dynamic movement. Our findings showed that the EMG activities of the biceps brachii and triceps brachii muscles decreased by 2%MVIC and 3%MVIC respectively, after cross-aligned taping. Similarly, parallel-aligned taping produced decreased EMG activity of 3%MVIC in these muscles. Furthermore, the EMG activities of the flexor carpi radialis and extensor carpi radialis muscles decreased by 4%MVIC and 2%MVIC respectively, with parallel-aligned taping. In a study conducted to explore the effects of elastic taping, Slupik et al (2007) reported that the application of taping increased EMG activities of the vastus medialis muscle after 24 hours, as well as the increase of motor activity in this muscle after taping, and even following its removal. Therefore, the influence of taping on muscle activity may be related to neuromuscular control and proprioceptive feedback factors. Their findings support the results of our study.

Many studies have provided evidence for the favorable effects of taping. Osterhues (2004) reported that the effects of taping were similar to those of pharmacological treatment, which has been commonly employed by clinicians to control proprioceptors and other skin sensory receptors. Da Costa et al (2013) found that the UL function in cerebral palsy children can be enhanced by optimizing postural alignment of the shoulder and trunk and supporting wrist and finger function using taping. Additionally, some studies reported that taping possibly changes the onset time and latency time of muscles as well as muscle activity, which is helpful for reinforcement of the motor control mechanism (Mostafavifar et al, 2012; Williams et al, 2012).

However, as found in this study, cross-aligned taping did not create significant differences in the flexor carpi radialis and extensor carpi radialis muscles. Biceps brachii and triceps brachii muscles can be clearly distinguished from other muscles. However, it is hard to distinguish each individual muscle from the many muscles in the forearm as they may be activated simultaneously during wrist and hand movements. Hence, during EMG measurement, the crosstalk caused by adjacent muscles may disturb the EMG signal obtained from these muscles, which makes EMG data less accurate. Moreover, EMG data for all muscles did not show significant differences between cross-aligned and parallel-aligned taping conditions. The implication of this study is that the effects of taping are not dependent upon the tape application direction. When applied over the biceps brachii muscle, an elastic tape stretched around the skin can produce an increase in elbow peak torque while performing muscle contraction, and this increase appeared to be related to aspects of mechanical muscle length and alignment, thereby leading to improvement of sensory-motor function and proprioception (Aktas and Baltaci, 2011; Fratocchi et al, 2013). Unlike the findings of his study, our study findings showed a tendency for decrease in the EMG activities of all muscles, with greater decline in parallel-aligned taping than in the no taping condition. Therefore, the results of this study should prompt further investigation of the effects of taping with the different application directions on muscle activity. The current study set forth a hypothesis that the effect of taping on muscle activity may be different depending upon the tape application direction; however, the findings did not support this hypothesis.

We recognize that this study has some limitations, which can be improved by further studies. First, recruitment of a small number of subjects greatly limits the generalizability of these results to the entire population. Second, our study focused only on the initial effect after the taping intervention, and not on the maintenance effect. The long-term effect needs further exploration. Finally, this study did not include information about kinematic data obtained from motion analysis. Further studies are needed, with a larger sample size, a longer duration, and involving taping on populations presenting with musculoskeletal problems, which can be evaluated with motion analysis to describe the possible mechanisms of neuromuscular control.

Conclusion

In general, taping has been used to improve neuromuscular control, body posture, and musculoskeletal alignment in clinical settings by affecting muscle activity, and it may be an advantageous option for the encouragement of therapeutic strategies for functional improvement. This study aimed to evaluate the differences in muscle activity between cross- and parallel-aligned taping, and to compare the effects of these 2 methods. The findings demonstrated that taping may be helpful in decreasing muscle activity regardless of the direction of tape application, as there were no significant differences between cross- and parallel-aligned taping conditions. This study provides useful information to future researchers regarding the influence of taping on muscle activity.

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