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Multi-time Scale Decarbonization Coordination Strategy of Electric Vehicle Fleets Considering Transportation and Electricity Coupling

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Abstract

Introduction: Reduced grip strength (GS) during daily activities can lead to numerous problems, making the strengthening of relevant muscles a primary goal in rehabilitation. One effective method to enhance GS is the use of kinesio tape (KT). This study aims to compare the effects of different KT application methods on GS.

Methods: In this quasi-experimental study, 30 healthy individuals of both genders, with an average age of 24.57 ± 3.92 years, were selected using simple non-random sampling. Over five consecutive days, with 48-hour intervals, participants received different KT applications on the extensor region of the forearm. These methods included: I-shaped from origin to insertion, I-shaped from insertion to origin, Y-shaped from origin to insertion, Y-shaped from insertion to origin, and a control group with no KT application. GS was measured using a dynamometer before and immediately after applying the KT.

Results: The findings indicated that all KT methods, both I-shaped and Y-shaped, significantly increased GS ($p<0.001$). There was a significant difference between the KT methods and the control group ($p<0.001$). However, no significant difference was found between the various I-shaped methods ($p>0.05$) or between the different Y-shaped methods ($p>0.05$). Notably, there was a significant difference between the I-shaped and Y-shaped methods in both directions, with the I-shaped method showing a greater increase in GS compared to the Y-shaped method ($p<0.001$).

Conclusion: All KT application methods effectively increase GS. Therefore, any of these methods can be utilized based on the therapist's and patient's preferences when KT is needed to enhance GS. However, it should be noted that applying KT using the I-shaped method, from the origin to the insertion in the forearm extensor region, has the greatest impact on increasing GS.

Keywords: Kinesio tape, Grip strength, Forearm extensor region

Introduction

Grip strength (GS) plays a crucial role in many daily functional activities, such as grasping and carrying objects (1). Factors influencing GS include age, gender, body mass, occupation, individual rest, physical activity levels, upper limb muscle strength, nutrition, pain in the upper limb, and sensory system dysfunction in the upper limb can all influence GS (2). In assessing upper limb disorders, GS serves as a metric for determining the extent of damage. A decrease in GS can lead to significant challenges in performing daily activities, making muscle strengthening a primary goal in rehabilitation (3).

GS results from the co-contraction of the flexor and extensor muscles of the forearm (3, 4). During this process, the extrinsic flexor muscles of the fingers provide a strong gripping force and serve as the primary movers (5). However, the strength of the wrist extensor muscles is also crucial, as it significantly correlates with GS.

Strengthening these muscles, particularly when positioned at 30 degrees of extension and 5 degrees of ulnar deviation, has been shown to enhance GS (3). The wrist extensor muscles contribute to stability by providing a counteracting force against the flexor muscles through compressive force on the metacarpophalangeal joints. Additionally, they help maintain the length-tension relationship, leading to stronger contractions in the flexor muscles (6, 7).

One common therapeutic method for increasing GS is kinesio taping (KT). Previous studies indicate that KT applied to various forearm regions (flexor, extensor, or both) can improve GS; however, the effect of KT on the extensor region alone is significantly more pronounced due to the postural and tonic nature of this muscle group and the higher density of hair follicles in this area (6).

Measuring GS strength is a useful, simple, and relatively inexpensive clinical method that provides valuable quantitative data for the therapist. It is an important component of hand rehabilitation, used to assess hand functional capacity, determine the extent of patient disability, establish treatment baseline, select appropriate therapeutic methods, evaluate treatment effects, and assess the patient’s readiness to return to their professions (8, 9). Additionally, some researchers suggest that GS can serve as a reliable indicator of overall upper limb strength, overall body strength, back extensor muscle strength, and respiratory muscle strength (10).

It is believed that the path and direction of KT application can influence muscle strength differently. Specifically, applying KT from the muscle's origin to its insertion is considered facilitative, while applying it from insertion to origin is deemed inhibitory (11). However, conflicting results exist regarding this issue. Few articles compare these two methods, with most studies investigating effects in body regions other than the forearm (11-14). Studies examining KT effects on the forearm generally focus on one of the facilitative or inhibitory methods without direct comparisons, yielding inconsistent results. Some studies have found the origin to insertion method effective (3, 6, 15-17), while others have reported it ineffective (18-20). Some researchers regard the insertion to origin method as ineffective (21, 22), while a study by Kai et al. (23) compared both methods and concluded that neither was effective.

The effect of KT application shape is another debated topic among researchers. It is suggested that KT can be applied in either I or Y shapes to achieve facilitative or inhibitory effects. Unfortunately, no study has compared these two methods in the forearm or other body areas, with most focusing on a single method at a time Some of these studies investigated the effects of these methods in body regions other than the forearm (11-14, 20). Numerous studies have examined the effects of KT shapes on the forearm, but their findings remain inconsistent (3, 6, 15-19, 21-23).

Given the importance of increasing GS and the conflicting studies regarding the effects of different KT application directions and shapes on muscle strength, it is essential to investigate which KT application direction or shape has a greater impact on increasing GS. Therefore, the objective of this study was to assess the effects of various KT methods on GS.

Materials and Methods

Participants

In this quasi-experimental study, 30 healthy volunteers of both genders were selected based on specific inclusion and exclusion criteria. Inclusion criteria included non-athletes aged 18 to 30 years with a BMI between 22 and 25 kg/m². Exclusion criteria comprised allergies to KT, limited range of motion, deformities, fractures, arthritis, tendonitis of upper extremity joints, systemic or neurological disorders affecting GS within the last six months, skin diseases or scar tissue in the testing area, and the use of performance-enhancing drugs, psychoactive substances, or alcohol within 48 hours prior to the test.

The study protocol was approved by the Ethics Committee of Ahvaz Jundishapur University of Medical Sciences (Ahvaz, Iran), with approval code IR.AJUMS.REC.1402.610.

All participants were provided with written information about the study's aims and purposes. If they agreed to participate, they signed a consent form. Participants were informed of the study's safety and their right to withdraw at any time.

Sampling method

Participants were selected from Ahvaz Jundishapur University of Medical Sciences through a simple, non-random sampling method.

Data Collection

In this study, five conditions were examined: I-shaped from origin to insertion, I-shaped from insertion to origin, Y-shaped from origin to insertion, Y-shaped from insertion to origin, and a control condition with no KT application. KT was applied with 50% stretch, and GS was measured before and immediately after the application on the dominant hand (6).

First step

Participants sat on a chair with armrests, positioning their arm alongside the body, with the elbow flexed at 90 degrees of flexion and the forearm and wrist in a neutral position. They were instructed to grip the lever arm of a calibrated dynamometer (digital pinch/grip analyzer, MIE, England). After a few gentle presses to familiarize themselves with the device, participants squeezed with maximum effort three times for 3 seconds each, with 60 seconds of rest between attempts. The average of these measurements was recorded as GS (in kilograms) before applying KT. Next, with the elbow fully extended, the forearm pronated, and the wrist in a neutral position, the distance from the lateral epicondyle of the elbow to the base of the metacarpal bones of the wrist was measured and multiplied by 83% to determine the length of KT with 50% stretch. The calculated length of KT was cut, and after removing the backing, it was applied in an I-shaped from the lateral epicondyle (the origin of the wrist and finger extensor muscles) to the base of the metacarpal bones (the insertion of the same muscles). After that, GS was measured again in the same position. KT was then removed from the participant's skin. Notably, 2 centimeters above and below the application points, the tape was applied without stretch (6).

Second step

All procedures were the same as in the first step, except that in this step, KT was applied in an I- shaped from the insertion of the extensor muscles to the origin.

Third step

All procedures were identical to the first step, but in this step, KT was applied in a Y-shaped. The KT was cut in the middle to form a Y-shaped. The base of the Y was applied without stretch on the lateral epicondyle, and the two arms of the Y were stretched from both the outer and inner sides of the extensor muscles to the base of the metacarpal bones.

Fourth step

All procedures were the same as in the third step, but in this step, KT in the Y-shaped was applied from the insertion of the extensor muscles to the origin.

Fifth step

All procedures were the same as in first step, except no KT was applied in this step.

It is important to note that the five steps of the study were selected and conducted randomly.

Data Analysis

Data were analyzed using SPSS version 21.0 (SPSS Inc., Chicago, IL, USA). The Kolmogorov-Smirnov (K-S) test was employed to assess the normality of the data distribution. All variables exhibited a normal distribution; therefore, a paired t-test was used to compare pre- and post-measurements within each test. Repeated measures

ANOVA was applied to compare between different KT groups, with the Bonferroni post-hoc test used for multiple comparisons. The alpha level for all statistical tests was set at 0.05.

Results

Thirty individuals (15 males and 15 females), with an average age of 24.57 ± 3.92 years, height of 172.23 ± 9.44 cm, weight of 70.10 ± 8.95 kg, and BMI of 23.52 ± 0.88 kg/m², participated in the study. GS significantly increased in all KT application methods (P < 0.001 for all cases), but showed no significant change without KT application. Detailed information is presented in Table 1. After data normalization, repeated measures analysis revealed a significant difference between the various KT application methods (P < 0.001, Table 2). Further analysis using Bonferroni correction for post-hoc tests is shown in Table 3 and Figure 1. Given the relatively small sample size, the Bootstrap resampling method was employed to ensure the robustness and reliability of the findings. This approach allowed for generating more accurate confidence intervals, and the results obtained through Bootstrap confirming the statistical significance of the findings.

Table 1. Comparison of GS before and after KT (n=30). [a,b]

Methods	Before	After	P-value
I shape OI	39.71 (8.71)	48.76 (10.48)	< 0.001
I shape IO	39.75 (8.73)	48.40 (10.38)	< 0.001
Y shape OI	39.34 (8.75)	44.22 (10.20)	< 0.001
Y shape IO	39.35 (8.75)	44.00 (10.07)	< 0.001
Control	39.09 (8.69)	39.21 (8.75)	108

[a] Values are presented as mean (SD)

[b] Abbreviation: GS: grip strength; KT: kinesio taping; OI: origin to insertion; IO: insertion to origin.

Table 2. Comparison of difference KT methods on GS. [a,b]

Methods	Difference	P-value
I shape OI	22.92 (0.51)	< 0.001
I shape IO	21.90 (0.50)	
Y shape OI	12.24 (0.49)	
Y shape IO	11.69 (0.41)	
Control	0.30 (0.19)	

[a] Values are presented as mean (SD)

[b] Abbreviation: GS: grip strength; KT: kinesio taping; OI: origin to insertion; IO: insertion to origin.

Table 3. Comparison of difference percentages of KT methods on GS (n=30). [*]

Variables		Mean difference (SE)	P-value
I shape OI	**I shape IO**	1.02 (0.34)	0.054
	Y shape OI	10.68 (0.69)	< 0.001
	Y shape IO	11.23 (0.66)	< 0.001

	Control	22.62 (0.48)	< 0.001
I shape IO	**Y shape OI**	9.66 (0.64)	< 0.001
	Y shape IO	10.20 (0.61)	< 0.001
	Control	21.59 (0.51)	< 0.001
Y shape OI	**Y shape IO**	0.54 (0.38)	1.000
	Control	11.93 (0.55)	< 0.001
Y shape IO	**Control**	11.38 (0.43)	< 0.001

* Abbreviation: SE: standard error; GS: grip strength; KT: kinesio taping; OI: origin to insertion; IO: insertion to origin.

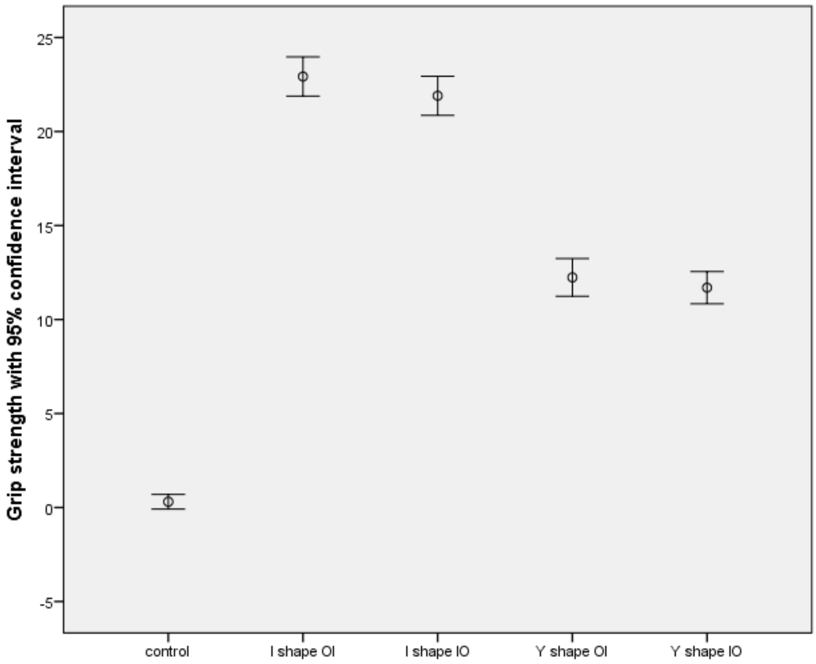

Fig 1. Different percentages of KT methods on GS (n=30). *

* Abbreviation: GS: grip strength; KT: kinesio taping; OI: origin to insertion; IO: insertion to origin.

Discussion

The objective of this study was to assess the effects of various KT application techniques on GS in the extensor region of the forearm. Four distinct configurations of KT were applied: I-shaped KT from origin to insertion, I-shaped KT from insertion to origin, Y-shaped KT from origin to insertion, Y-shaped KT from insertion to origin, and a control condition without KT application. This investigation aimed to determine which method resulted in the most significant enhancement of GS. The study yielded three main findings:

1) Application of KT to the forearm (both I and Y-shaped methods) results in increased GS: This finding is consistent with studies by Hosseini et al. (16), Kim et al. (3), Mahmoud et al. (15), Dewir et al. (17), and Mohammadi et al. (6), while contradicting the results of Limmer et al. (21), Zanchet et al. (18), Chang et al. (22), Cai et al. (23, 24), and Moezy et al. (19). KT stimulates mechanical receptors in the skin, leading to changes in the nervous system that enhance muscle excitability (25). The increase in muscle strength with KT is attributed to enhanced proprioceptive function and increased muscle tonicity resulting from the stimulation of muscle receptors (12). KT impacts muscle strength both directly and indirectly. The direct effect stems from the pressure and stretch applied to the skin, which increases stimulation of mechanoreceptors and sensory feedback in the taped area, thereby facilitating muscle contraction (11). The indirect effect is related to pain reduction and inflammation alleviation. KT stimulates sensory receptors and activates spinal inhibitory systems, reducing pain. It also improves blood and lymph circulation, which helps decrease inflammation. Repeated KT application reinforces this feedback loop, enhancing muscle strength even in the absence of continuous use (10).

Another proposed mechanism for the strength increase with KT is that it lifts the skin, fascia, and connective tissue, creating more space for muscle contraction. This increase in muscle tone allows muscles to remain in a shortened position, optimizing actin-myosin interactions and ultimately enhancing force production (3, 26). KT continuously stimulates mechanoreceptors, sending more sensory signals to the central nervous system, which lowers the threshold of motor neurons and increases motor cortex excitability. This facilitates the recruitment of motor units in the muscles, aiding in the production of a more optimal contractile force (3, 27). Previous studies have also reported increased electrical activity in muscles after applying KT to the relevant skin area (28-30).

Extensor and flexor muscles can be classified as tonic (postural) and phasic muscles, respectively. Tonic muscles, which are primarily composed of type I (slow-twitch) muscle fibers, have a lower activation threshold compared to phasic muscles (31). This makes KT, which stimulates low-threshold receptors, more effective on extensor muscles. Furthermore, the extensor side of the forearm has a higher density of hair follicles than the flexor side. This increased number of hair follicles beneath the tape can enhance muscle stimulation (32). Consequently, the observed increase in GS after applying KT to the extensor muscles of the forearm may be related to the tonic characteristics of these muscles and the greater number of hair follicles in that region.

2) GS increases regardless of KT application direction: This finding aligns with studies by Dewir et al. (17), Kim et al. (3), Hosseini et al. (16), Mahmoud et al. (15), and Mohammadi et al. (6), but contrasts with studies by Limmer et al. (21), Chang et al. (22), Cai et al. (23), Zanchet et al. (18), and Moezy et al. (19). It is generally believed that the direction of KT application may yield different effects on muscle strength. The application from muscle origin to insertion employs a facilitatory technique, while applying from insertion to origin is considered inhibitory (11). However, the results of this study, as well as similar studies, suggest that the concept of inhibition may not be accurate, as positive results were observed in both directions.

Few studies have directly compared these two methods, with most focusing on other body parts. For instance, Lemos et al. (12) and Lee et al. (11) found no positive effects from facilitatory or inhibitory techniques. Conversely, Choi and Lee (13) reported that both methods equally increased strength, and Fukui et al. (14) found that both methods enhanced strength, with the inhibitory technique being more effective. However, studies focusing on the forearm typically address only one of the facilitatory or inhibitory and do not compare both methods, leading to inconsistent findings. Some studies have found that the application of KT from the origin to the insertion is effective (3, 6, 15-17), while others have reported it to be ineffective (18-20). Similarly, some researchers consider the application from the insertion to the origin to be ineffective (21, 22). Notably, Cai et al. (23) compared both methods and found that neither approach was effective.

Kase (33) defines the application of KT from the origin to the insertion as facilitation and the application from the insertion to the origin as inhibition. However, based on the findings of this study and similar research, using the term 'inhibition' to describe the application of KT may be inaccurate, as both methods have demonstrated positive effects on strength enhancement. Overall, it is important to note that KT, when applied to the skin and stimulating proprioception, necessarily increases strength.

Researchers have argued that KT stimulates muscle spindles and facilitates muscle contraction via stretch mechanoreceptors. According to the cutaneous fusimotor reflex theory, various tactile stimuli, such as contact and vibration, activate gamma motor reflexes, thereby enhancing muscle strength (34). Additionally, the tactile stimulation from KT influences gamma motor neurons by inhibiting Ia afferent input, which contributes to increased muscle strength (35). Therefore, the direction of KT application does not significantly affect the underlying mechanism of muscle strength enhancement.

3) The I-shaped KT method resulted in a greater increase in GS compared to the Y-shaped method: The impact of shape KT application is a topic of debate among researchers. While it is suggested that both I and Y shapes can yield similar effects, comprehensive comparative studies are notably lacking. Unfortunately, we could not find any studies that compares these two methods, whether applied to the forearm or other body parts. Most studies have only considered one of these methods. Some of these studies examined the effects of the two methods on body parts other than the forearm. For instance, studies by Choi and Lee (13) and Fukui et al. (14) reported positive effects of the I-shaped method, whereas Lemos et al. (12) found it to be ineffective. In contrast, Lee et al. (11) and Fu et al. (20) reported the Y-shaped method as ineffective. Although numerous studies have investigated the effect of KT shape on the forearm, their findings remain inconsistent. Kim and Kim (3), Mahmoud et al. (15), Mohammadi et al. (6), and Dewir et al. (17) found the I-shaped method effective in increasing GS, while Zanchet et al. (18) and Cai et al. (23) reported it as ineffective. On the other hand, Hosseini et al. (16) identified the Y-shaped method as effective, while Limmer et al. (21), Moezy et al. (19), and Chang et al. (22) reported it as ineffective. The discrepancies in these findings may be attributed to variations in KT application techniques, levels of applied tension, sample characteristics, duration of KT application, and methods used for measuring GS.

In this study, comparing the two KT methods, the I-shaped method showed a significantly stronger effect on increasing GS compared to the Y-shaped method. The I-shaped method may provide more extensive proprioceptive stimulation due to its coverage of the entire skin surface in the area, leading to greater strength enhancement. In contrast, the Y-shaped method covers only the lateral parts of the skin, resulting in less effective proprioceptive stimulation and a smaller increase in strength (36).

Additionally, the I-shaped method applies KT directly and uniformly over the muscle, facilitating even force distribution along the muscle fibers. This may reduce unnecessary tension and enhance muscle function. In contrast, the more complex Y-shaped application could lead to less uniform force distribution. Furthermore, many participants in this study reported that the I-shaped method provides greater comfort and support. This psychological and emotional effect, arising from increased confidence, can positively influence performance and contribute to enhanced muscle strength.

Conclusion

The findings of this study can aid in improving rehabilitation methods and increasing efficiency in individuals with reduced GS. Given the demonstrated effectiveness of KT, especially the I-shaped method, it is recommended as a useful tool in rehabilitation processes. Furthermore, since no significant differences were observed between application directions, both directions can be used based on patient comfort and needs.

This study has some strengths and weaknesses points. Among its strengths are the simultaneous comparison of different KT application shapes (I and Y) and various application methods (from origin to insertion and insertion to origin). However, weaknesses include the small sample size and the focus on the immediate effects of KT. Future research should investigate the long-term effects of these application methods, as this may yield different results.

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