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Original Article

Trend of effects of various kinesiotaping methods on muscle contraction performance during fatigue: A randomized, crossover study

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ABSTRACT

Objectives: This study aims to investigate the effects of different kinesiotaping methods on muscle contraction of fatigued biceps.

Patients and methods: Between April 01, 2019 to September 30, 2019, a total of 24 adults (11 males, 13 females; mean age: 31.8±6.1 years; range, 24 to 47 years) were recruited in the study. Each participant needed to receive all four types of tape attachment, including facilitation attachment (from origin to insertion), relaxation attachment (from insertion to origin), cross attachment, and control attachment after fatigue procedure. The order of taping approaches was randomly assigned. The outcome parameters were maximal isometric contraction strength, peak contraction speed, maximal 10-s power, and isokinetic contraction work.

Results: The results revealed no significant differences among the four tape attachment methods for any of the parameters. However, the facilitation attachment exhibited the highest trend of improvement in all muscle contraction performance during fatigue, and the cross attachment exhibited the lowest trend of improvement in maximal isometric contraction and speed.

Conclusion: None of the kinesiotape attachment methods significantly enhanced the contraction of fatigued muscles regardless of the attachment direction, including origin to insertion, insertion to origin and cross. Facilitation attachment exhibited the most effective trend of improvement and is, therefore, recommended for clinical applications. Cross attachment was not suggested to use due to the least effective trend.

Keywords: Cross attachment, facilitation attachment, fatigue, kinesiotape, relaxation attachment.

Kinesiotape is commonly employed in clinical interventions. According to the inventor, Dr. Kenzo Kase,[1] tension caused by tape elasticity and attachment techniques affects the effects that kinesiotape produces, such as pain relief,[2] circulation increase,[3] proprioception enhancement,[4-6] neuromuscular control,[7] and muscle contraction improvement.[8-11] In addition to patients, kinesiotape is commonly applied by athletes to enhance their performance. Study have reported that reduced H-reflexes in fatigue muscles inhibit muscle strength and contraction speed and change proprioception,[12] thereby increasing the risk of injury.[13] Kinesiotape is widely recognized as an effective method to mitigate muscle fatigue.[14,15] However, certain researchers have suggested that it may not significantly enhance exercise performance and delay the self-perceived fatigue onset in healthy individuals.[16,17] The impact of kinesiotape on fatigued muscles remains an area of uncertainty.

According to Dr. Kase, inhibiting and inducing muscle contraction involve opposite attachment directions. To induce muscle contraction, tape should be attached from the origin to the insertion. Attaching from the insertion to the origin is referred as the inhibition method;[1] alternatively, the tape can be attached perpendicular to the muscle fiber to relax the muscles.[18] However, different opinions have recently been presented regarding

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tape approaches. Choi and Lee[19] indicated that kinesiotape enhances the strength of fatigued muscle regardless of whether the attachment direction was consistent with the direction of muscle contraction; this is different from the theory that has been applied in the clinical setting.[10,11,20,21] However, few studies have investigated the attachment methods of kinesiotape to date.[19,22,23] Instead, most studies have compared the effects between kinesiotape and placebos and have shown that kinesiotape is limited in effectiveness or completely ineffective.[24-28]

Inconsistency between the results of existing studies may be related to the high heterogeneity in attachment methods. A study showed that attachment in the direction of extensors did not effectively enhance muscular endurance in patients with lower back pain.[25] Another study reported that cross attachment significantly improved patients' muscular endurance.[3] Studies have adopted inconsistent attachment methods, as well as different outcome definition and measurement. Such inconsistencies might lead to the lack of reliably references for relevant research and practice. Most of those studies have employed contraction strength as an indicator of muscle capacity.[22,29] However, sports performance is affected by not only muscle strength, but also contraction speed,[30] muscular endurance, and movement control.[30,31]

While exploring treatment that involves the use of kinesiotape, the effect of attachment method on the effectiveness of kinesiotape must be considered, and accurate instruments are required to measure muscle contraction. In the present study, we aimed to investigate the effects of different kinesiotaping methods on muscle contraction of fatigued biceps and to analyze motor control capacity of the participants.

PATIENTS AND METHODS

Study design and study population

This double-blind, randomized, crossover study design was conducted at Taoyuan General Hospital, Ministry of Health and Welfare, Department of Physical Medicine and Rehabilitation between April 01, 2019 to September 30, 2019 (ClinicalTrials.gov: NCT04487184). A total of 24 healthy participants (11 males, 13 females; mean age: 31.8±6.1 years; range, 24 to 47 years) underwent the application of four different kinesiotape attachment methods as illustrated in Figure 1: A) facilitation attachment (from origin to insertion), B) relaxation attachment (from insertion to origin), C) cross attachment, and D) control. The four attachment methods were arranged into 24 distinct sequences such as ABCD, ABDC, ACBD, ACDB, and so on (Appendix 1). To ensure randomization, we utilized a random string generator to create these attachment order combinations and randomly assigned them to 24 individuals. All tape attachment procedures were performed by a therapist with clinical experience. Participants were blindfolded throughout the process. To maintain participant blinding, tapes were attached and then removed during the control method. After the procedure was completed, the taped areas were concealed under loose-fitting, long-sleeved shirts. To ensure double-blinding, neither the assessors nor the participants were informed of the order of the attachment methods. The changes of muscle contraction in fatigued biceps brachii were evaluated for the effect of kinesiotape.

Patients or participants

The participants were healthy adults aged 20 years or older. Those who were unable to follow verbal instructions, had open wounds, or were allergic to kinesiotape were excluded. The study protocol complied with the provisions of the Declaration

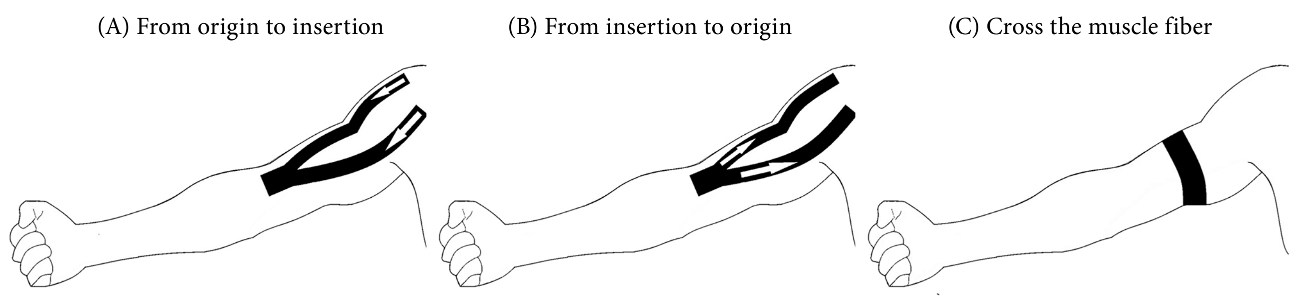

Figure 1. The attachment methods of kinesiotape.
(A) Facilitation (B) Relaxation (C) Cross.

of Helsinki, and was approved by the Medical Ethics and Institutional Review Board of Taoyuan General Hospital, Ministry of Health and Welfare (date: 24.12.2018, IRB no: TYGH107038). The informed consent was received from all participants and their rights were protected. With the statistical power set at 90% and α≤0.05, at least 72 pieces of data were required for this study.[8] As there were four distinct attachment methods, each method was required to comprise 18 participants. However, to ensure

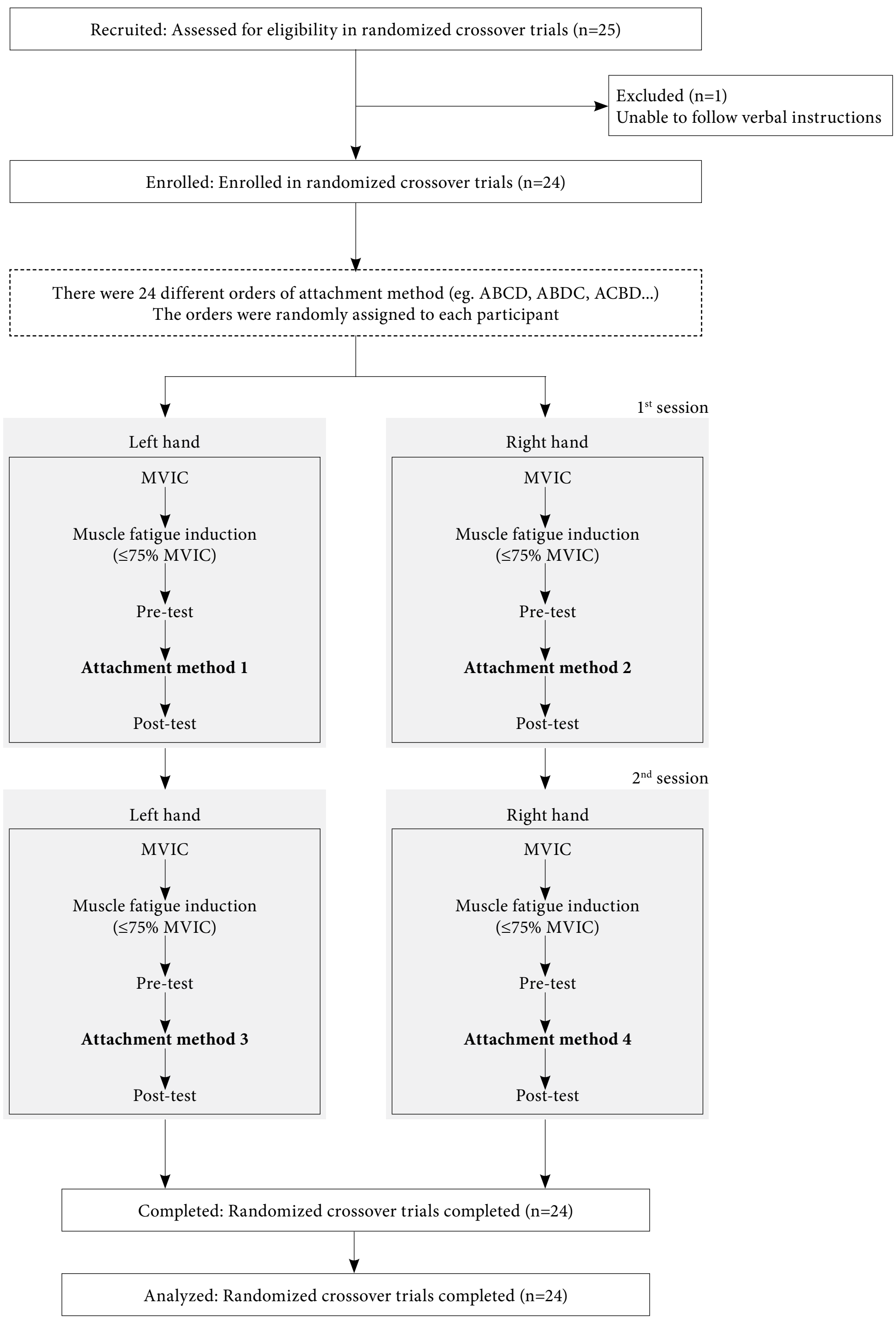

Figure 2. Study flowchart.

A: Facilitation; B: Relaxation; C: Cross; D: None; MVIC: Maximal voluntary isometric contraction.

the randomness of process, we considered a total of 24 attachment order combinations (e.g., ABCD, ABDC, ACBD...) and increase the recruitment from 18 to 24 participants. Consequently, the final statistical power reached 97%, with a total of 96 data points (24 participants × 4 methods).

Procedures

Two sessions, separated by a time interval of one week, were conducted using all four attachment methods. The selected method orders were randomly assigned to both arms. The first and third attachment methods would be applied to the left hand, while the second and fourth methods would be applied to the right hand (Figure 2). The participants performed elbow flexion in a standing position using the Ultimate Physical Therapy System (PrimusRS, BTE, USA). Before the pre-test started, all participants underwent a fatigue induction procedure. Initially, they underwent peak torque measurement, followed by repeated elbow flexion at an angular velocity of 60°/s.[19] The point which the power of biceps concentric contraction decreased to 75% of the initial power due to repeated contraction was recorded as the point of muscle fatigue. Subsequently, a pre-test was conducted. To minimize the natural recovery from fatigue, the kinesiotape attachment procedures were finished within 2 min before the post-test (Figure 2). The ultimate physical therapy system was used to assess pre- and post-test differences in four parameters, including maximal isometric contraction strength, peak contraction speed, maximal 10-s power, and isokinetic contraction work.

According to the attachment methods, the anchor of kinesiotape (Kinesio Tex Classic Tape) would be attached to radial tuberosity (bicipital aponeurosis), coracoid process and supraglenoid tubercle (located just beneath the acromioclavicular joint), or biceps muscle belly. Based on Kase et al.,[1] the facilitation attachment and relaxation attachment methods involve applying paper-off tension which is thought to be 25% tension. In contrast, tension level of 50% was used for cross attachment method.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 22.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were expressed in mean ± standard deviation (SD), median (min-max) or number and frequency, where applicable. The Kolmogorov-Smirnov test was used to survey the normal distribution of all the parameters. Initially, the Student t-tests were performed to examine differences between groups. However, to minimize the risk of type I errors resulting from repeated t-tests, one-way analysis of variance (ANOVA) was conducted for the continuous variables. A p value of <0.05 was considered statistically significant.

RESULTS

Baseline and demographic data of the participants are shown in Table 1. The results revealed significant intragroup improvements in the average values of maximal isometric contraction and peak contraction speed for all four attachment methods. The maximal 10-s power improved substantially in the facilitation and cross attachment groups, but no significant

TABLE 1
Baseline and demographic data of participants (n=24)

Demographic	n	%	Mean±SD
Age (year)			31.8±6.1
Sex			
Male	11		
Female	13		
Height (cm)			166.90±7.84
Body weight (kg)			65.89±13.99
Body mass index (kg/m^2)			23.48±3.65
Exercise frequency (sets/week)			1.96±2.03
Dominant side (right)		91.7	
Delayed onset muscle soreness		87.5	

SD: Standard deviation.

TABLE 2
Pre- and post-test differences in each group (n=24)

	MVIC	Pre-test	Post-test	Difference	Group
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	*p*
Max isometric contractions (n)					
Group					0.811
A	111.55±37.23	79.55±23.32	93.56±26.87	14.01±10.85**	
B	106.69 ±32.07	78.29±22.20	90.14±30.03	11.85±16.57*	
C	112.20±33.77	83.20±24.08	93.67±28.23	10.47±8.87**	
D	109.24±34.36	80.43±27.53	91.72±26.84	11.29±14.65*	
Peak speed (°/s)					
Group					0.443
A		46.33±19.39	60.96±25.65	14.63±16.30**	
B		43.67±20.06	58.00±24.88	14.33±13.16*	
C		48.71±23.35	58.38±29.67	9.67±12.71**	
D		48.46±23.98	58.21±24.48	9.75±14.40*	
Power in 10 second (W)					
Group					0.804
A		17.30±7.01	20.45±8.17	3.15±4.86*	
B		18.35±8.90	20.84±11.12	2.49±6.68	
C		18.65±8.88	21.37±9.99	2.73±5.24*	
D		18.45±9.49	20.05±8.64	1.60±5.49	
Isokinetic contraction (J)					
Group					0.800
A		230.88±65.37	236.25±85.17	5.38±48.16	
B		224.71±78.45	225.88±80.53	1.17±45.60	
C		236.21±69.36	237.29±81.81	1.08±35.22	
D		240.50±85.32	234.17±79.71	-6.33±33.82	

MVIC: Maximal Voluntary Isometric Contraction before fatigue; SD: Standard deviation; Group A: Facilitate; Group B: Release; Group C: Cross; Group D: None; * Pre-post *p* value <0.05; ** Pre-post *p* value <0.001

changes were identified in isokinetic contraction. In the intergroup comparison, no significant differences were identified in the improvements of any of the four parameters (Table 2).

The raw data were visualized in a graph. The facilitation attachment group exhibited the highest increase in the maximal isometric contraction, followed by the relaxation, control, and cross attachment groups. The same trend was observed for the increase in the peak contraction speed. The facilitation attachment group exhibited the highest increase in the maximal 10-s power, followed by the cross attachment, relaxation, and control groups. Finally, the facilitation attachment group exhibited the highest increase in isokinetic contraction work, followed by the relaxation, cross attachment, and control groups. Although no statistically significant difference was observed between these groups in any of the parameters, the facilitation attachment group exhibited the highest trend of improvement in all the parameters after the test, which enhanced the contraction of fatigued muscles. Conversely, the cross-attachment group exhibited the lowest trend of improvement in maximal isometric contraction and contraction speed (Figure 3).

DISCUSSION

In the present study, we assessed the effects of kinesiotape attachment methods on the biceps during muscle fatigue. To prevent interference of different levels of muscle fatigue on the research results, instruments were used to quantify participants' fatigue levels. The muscle soreness ratios after the test were also recorded to verify whether the participants had sustained fatigue. This information helps us to identify the proportion of participants who did not exert maximal effort during the test and how much that might affect the results.[32-34] The results revealed that nearly 90% of participants experienced delayed muscle soreness, signifying their voluntary adherence to the research design. This high percentage contributed to the consistency of muscle fatigue

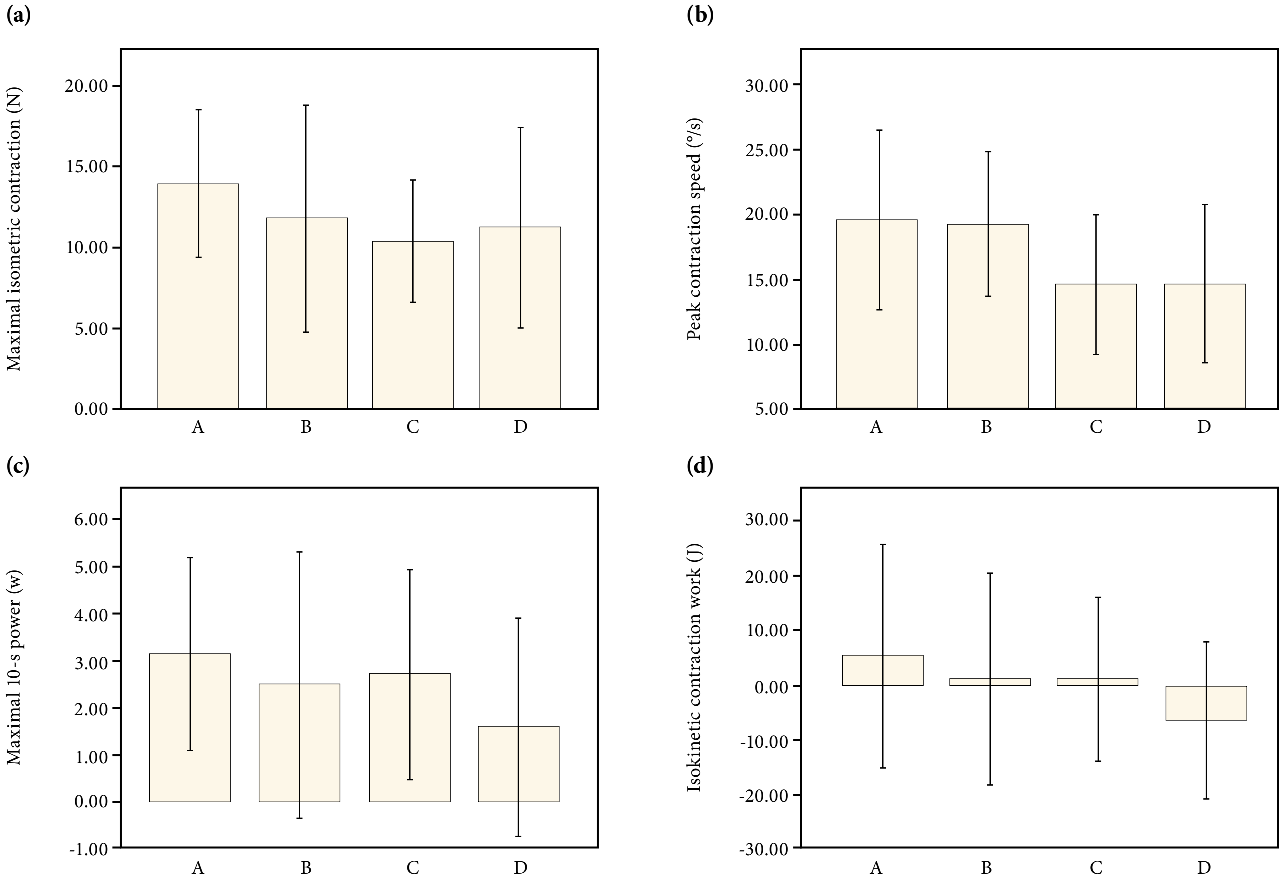

Figure 3. Pre- and post-test differences in each group. **(a)** Maximal isometric contraction strength. **(b)** Peak contraction speed. **(c)** Maximal 10-s power. **(d)** Isokinetic contraction work.

A: Facilitation; B: Relaxation; C: Cross; D: None.

across groups. No significant difference was observed between the experimental and control groups in terms of the performance of muscles contraction during fatigue.

The results of this study are consistent with a systematic review, which reported that kinesiotape did not enhance the limb muscle strength in healthy individuals.[28] However, another study focusing on fatigued muscles indicated that kinesiotape could enhance quadriceps strength during fatigue, regardless of whether it is applied from origin to insertion.[19] This implies potential therapeutic effectiveness for kinesiotape in fatigued muscles rather than in healthy individuals. However, the absence of a control group in that study left the impact of rest time on fatigue repair unclear. This study revealed that 2-min of rest enabled the recovery of muscles during fatigue. Literature data have shown that resting enables fatigued muscles to recover strength even without kinesiotapes. However, kinesiotape exhibits a more effective trend in enhancing maximal isometric contraction than does simple rest when it is attached along the muscle fiber rather than in the transverse direction.

In addition to muscle strength, peak contraction speed affects muscle agility, and continuous contraction power affects muscle endurance during sports. Poon et al.[26] compared the effects of kinesiotape, a placebo, and a control on muscle performance, focusing on speed and work parameters such as the time to peak torque and the total work of five muscle contractions. The results revealed no significant differences among the three groups. Similarly, in our study on fatigued muscles, we found no significant differences in peak contraction speed or continuous contraction performance among the four groups.

Study has applied isokinetic pulley systems to examine the effect of kinesiotapes on concentric and eccentric contraction strength of healthy individuals. The results indicated that the tapes increased the maximal isokinetic contraction strength.[8] However, in the present study, a different finding was reached regarding fatigued muscles. This difference was not only due to the levels of muscle fatigue, but also because of the definitions of the parameters employed in the present study. Although a higher maximal muscle strength during isokinetic contraction leads to higher work, muscles are not necessarily capable of continuous and efficient work throughout the contraction. In this study, we attempted to clarify whether satisfactory muscle control was possible during isokinetic contraction. Therefore, instead of focusing on maximal muscle strength, the muscle performance focused on was the total work generated during concentric and eccentric contractions. According to the results, no significant difference was found between the four groups in isokinetic contraction work, suggesting that kinesiotape did not provide significant benefits for motor control during body activities.

Although no significant differences were detected between the groups in any of the study variables, the graphical representation of the data indicated that the facilitation attachment group exhibited the highest trend of improvement in all parameters. In other words, facilitation attachment may improve muscle contraction most effectively. On the contrary, the cross-attachment group exhibited a lower degree of improvement compared to the control group in terms of maximal isometric contraction strength and peak contraction speed. This indicated that attaching kinesiotape in a transverse direction to muscle fibers may not effectively improve muscle contraction strength and speed. To put it simply, cross attachment was not suggested for enhancing maximal muscle contraction strength and speed due to the least effective trend.

Nonetheless, there are some limitations to this study. First, as this study focused on the immediate effect of tape attachment, changes in the effect over time were not explored. Thus, no conclusion was reached regarding the long-term effect of kinesiotape on the contraction of fatigued muscles. Second, to mitigate the influence of differing muscle fatigue levels on test results, efforts were made to standardize fatigue levels through instrument settings. Delayed muscle soreness was regarded as was used as an indicator that participants had exerted their full muscle strength. Although some participants were inconsistent in their levels of muscle fatigue, the data indicated that nearly 90% of the participants had exerted all their muscle strength. Compared to other studies, this research limitation was reduced to its minimum to improve the research credibility. Third, while the research method involves random assignment, which can effectively mitigate selection bias, it is of utmost importance to note that insignificant results may still occur due to greater variability in evaluations between the two hands.

In conclusion, none of the kinesiotape attachment methods significantly enhanced the contraction of fatigued muscles. However, facilitation attachment exhibited the most effective trend of improvement and is, therefore, recommended for clinical applications. Further well-designed, randomized-controlled, prospective studies are needed to confirm these findings.

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Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Idea, design, analysis, interpretation, writing the article, and critical review: H.J.Y.; Idea/concept,control/supervision,data collection and processing, analysis and interpretation, literature review, writing the article, and references: R.Y.W.

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APPENDIX 1

24 sequences of attachment method order.

1	A-B-C-D
2	A-B-D-C
3	A-C-B-D
4	A-C-D-B
5	A-D-B-C
6	A-D-C-B
7	B-A-C-D
8	B-A-D-C
9	B-C-A-D
10	B-C-D-A
11	B-D-A-C
12	B-D-C-A
13	C-A-B-D
14	C-A-D-B
15	C-B-A-D
16	C-B-D-A
17	C-D-A-B
18	C-D-B-A
19	D-A-B-C
20	D-A-C-B
21	D-B-A-C
22	D-B-C-A
23	D-C-A-B
24	D-C-B-A

A: Facilitate; B: Release, C: Cross; D: None.