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Original research

Kinesiology tape length and ankle inversion proprioception at step-down landing in individuals with chronic ankle instability

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ABSTRACT

Objectives: To determine the effect of different lengths of kinesiology tape (KT) on ankle inversion proprioceptive performance in individuals with or without chronic ankle instability (CAI).
Design: A repeated measures study.
Methods: Fifteen participants with unilateral CAI and fifteen participants with no CAI volunteered. The Ankle Inversion Discrimination Apparatus for Landing (AIDAL) was used to measure ankle proprioceptive acuity. All participants were tested under four KT conditions: no tape (baseline), short tape length (only foot and ankle complex involved), mid length (below the knee) and long length (above the knee) taping. After the baseline test, participants underwent the 3 different taping tests in a random order.
Results: Repeated measures ANOVA indicated that, compared to those without CAI, individuals with CAI performed significantly worse across the 4 different conditions ($F = 8.196$, $p = 0.008$). There was a significant KT main effect ($F = 7.489$, $p < 0.001$) and a significant linear effect ($F = 17.083$, $p < 0.001$), suggesting that KT significantly improved ankle proprioceptive performance in landing, and with longer tape length there was greater proprioceptive enhancement. Post-hoc analysis showed that for the CAI group, both mid length ($p = 0.013$, 95% CI = −0.063, −0.009) and long length ($p = 0.010$, 95%CI = −0.067, −0.011) taping can significantly improve ankle proprioceptive performance compared to no tape, whereas for the non-CAI group, ankle proprioceptive acuity was significantly improved only with long length taping ($p = 0.007$, 95%CI = −0.080, −0.015).
Conclusions: KT can be used to improve ankle inversion proprioceptive performance during landing in both individuals with and without CAI and increasing tape length may achieve greater proprioceptive improvement.

Practical implications

- Individuals with CAI performed worse than those without CAI in ankle inversion proprioceptive tasks involving step-down landing.
- KT can improve ankle inversion proprioceptive performance during landing, irrespective of ankle instability status.
- Variation in length of KT may have a different effect on individuals with or without CAI.

1. Introduction

Acute lateral ankle sprains occur frequently in sports involving jumping and landing, such as basketball, soccer and volleyball.[1,2] However, up to half of ankle sprains are not related to sports and may affect the general population.[3] Research evidence has shown an incidence rate of 2 to 7 acute ankle sprains per 1000 person-years in the general population.[4] The incidence of reinjury varies from 20 to 46% in different daily activities and sports[1] and causes a substantial burden to both patients and society. After the initial sprain, high recurrence rates and residual symptoms that may lead to chronic ankle instability (CAI) have been reported.[5]

CAI is typically associated with symptoms such as pain, swelling, and a feeling of "giving way", in combination with recurrent sprains after an initial ankle sprain.[5] It is generally believed that CAI is associated with proprioceptive impairments from the initial sprain.[6] Proprioception is defined as the ability to perceive sensory input from mechanoreceptors and integrate it with all relevant sensory information in order to determine body position and movement and produce an appropriate motor response.[7] There are three types of afferents responsible for providing proprioceptive signals: from mechanoreceptors located in the muscle spindles, from ligaments and joint capsules, and from the cutaneous tissues.[6] Although muscle spindles are thought to be the main source of proprioceptive input, ligaments and joints and cutaneous input are

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also important determinants for proprioceptive performance.[8] After ankle sprain, the mechanoreceptors in the ligaments, capsules, and cutaneous tissues around ankle joint are likely to be impaired, reducing information transmission and resulting in deficient ankle proprioception.[6] Thus, it is logical to turn to interventions that might increase cutaneous input around the ankle joint to enhance proprioception.

Bracing and taping can be used for providing additional cutaneous input to improve ankle proprioception in individuals with and without CAI, for preventive and rehabilitative purposes.[9] Kinesiology taping (KT) is one of the taping methods that has been widely used in a variety of sport setting and in the general population.[10] It has been argued that the elasticity of KT enables it to produce tension on the skin and subcutaneous tissue, thereby increasing cutaneous input and improving ankle proprioception.[11–13]

However, the effect of KT on ankle proprioception can be affected by many factors, such as taping technique and wearing duration.[10,13] In addition, since KT may improve proprioception by stimulating cutaneous input, it can be hypothesized that a longer length of tape would provide more proprioceptive feedback and thereby achieving better proprioceptive performance. However, other research has shown that the additional sensory input from taping may produce overload that can impair proprioceptive performance in those who have already have good proprioception.[12] To date, no studies have examined the effect of different lengths of KT on ankle proprioception. Because the answer will have important implications for ankle injury prevention and CAI intervention, the aim of this study was to determine the effect of different lengths of KT on ankle inversion proprioceptive performance in individuals with or without CAI. We hypothesized that: individuals with CAI may benefit from KT, and the effects may depend on the length of tape applied; while individuals without CAI may not benefit from the application of KT.

2. Methods

The study was approved by the Shanghai University of Sport Ethics Committee (approval number 102772020RT011) and written informed consent was obtained from participants before data collection.

The G*power software was used to determine the sample size for 90% power and an expected effect size of 0.25 SD units. It showed that to meet these specifications, there should be at least 15 participants for each group.

Thirty participants without specific sport experience were recruited. Fifteen had unilateral CAI, and the other fifteen had no CAI. Specific inclusion criteria for the CAI participants[14] were: (1) a history of at least 1 significant ankle sprain, (2) a history of at least 2 episodes of the ankle joint "giving way" in the 6 months prior to study enrolment, and (3) a score of ≤24 on the Cumberland Ankle Instability Tool (CAIT). Participants were excluded[14] from the study if they had any previous lower limb musculoskeletal surgeries, or acute symptoms of any lower extremity injury (pain, swelling, etc.), or had sprained an ankle in the last 3 months. Demographic information is reported in Table 1.

Table 1
Participant demographic information (Mean ± SD).

Characteristic	Group		Difference between groups
	CAI	Non-CAI	
N	15	15	–
Gender	M7 F8	M8 F7	–
Age (y)	23.9 ± 2.6	23.1 ± 2.0	$t = 0.957$, $p = 0.347$
Height (cm)	171.7 ± 8.1	167.7 ± 5.6	$t = 1.545$, $p = 0.133$
Weight (Kg)	63.0 ± 8.2	59.1 ± 7.3	$t = 1.386$, $p = 0.177$
CAIT score	21.1 ± 3.3	28.9 ± 1.1	$t = -8.755$, $p = 0.000$

SD = standard deviation, CAI = chronic ankle instability, N = number, M/F = male/female, CAIT = Cumberland Ankle Instability Tool.

KINDMAX 5 cm width kinesiology tape was used. The KT technique employed was that reported in the Jackson et al. study.[10] This KT technique consisted of four strips (Fig. 1). (1) The first strip was yellow and started from the dorsum of the foot around the first cuneiform and first metatarsal bones, extending upwards along the anterior tibia muscle. (2) The second strip was purple and started from the first metatarsal and passed around the lateral malleolus and extended proximally to just distal to the proximal head of the fibula. (3) The third strip was red and began at the medial malleolus and extended posteriorly along the postero-medial margin of the tibia and fibula. (4) The fourth strip was green and began just anterior to the lateral malleolus, extended under the plantar aspect of the foot, and was pulled up the transverse arch of the foot. The current study systematically modified the length of taping, including short length (only foot and ankle complex involved) (Fig. 1a), mid length (below the knee) (Fig. 1b) and long length (above the knee) (Fig. 1c) taping.

Moderate tension (25–35%)[15] was applied on each strip. The anchors at the beginning and the end of each tape strip were placed on the skin without tension. All the KT application procedures were conducted by the same experienced therapist, who was not involved in data collection and analysis and was blind to each participant's allocation.

The study involved testing under four conditions: barefoot, short taping, mid taping and long taping with KT. On the first day, the participants completed the test barefoot. Then they were tested at intervals of 24 h with each of the three different KT taping lengths. Tests with the three different taping conditions were conducted in random order. For the CAI group, the taped as well as the tested foot was the unstable side; and for stable ankle group, it was the dominant foot as determined by the foot used for kicking. No undertape was used, and the taped leg was not shaved.

The Ankle Inversion Discrimination Apparatus for Landing (AIDAL)[16] was used to test the acuity of ankle inversion proprioception during landing. This method has shown good test-retest reliability and validity in discriminating between individuals with and without CAI, and a significant correlation with subjective instability measured by CAIT.[16] The AIDAL (Fig. 2) consists of three parts: take-off platform (A), horizontal landing platform for the supporting foot (B) and slope landing platform for the testing foot (C). There were 4 landing platforms used to generate four different angles of ankle inversion: slope 1 = 10°, slope 2 = 12°, slope 3 = 14°, and slope 4 = 16°. The height difference between A and B was 10 cm. The mean lower limb muscle pre-activation time before landing is 120 ms (0.12 s),[17] putting this into the equation $S = 1/2gt^2$ gives a value of 0.07 m (7 cm) to ensure lower limb muscle pre-activation. Taking the variability of pre-activation time into consideration, therefore, a 10 cm difference between the take-off and landing platforms was used. A pre-experiment trial was conducted in 24 participants to test the security of the device. No one was injured or reported discomfort after the experiment.

Before data collection, familiarization with the four ankle inversion angles was conducted for three rounds in order (12 trials in total), so that the participant had the opportunity to experience and remember the four different ankle inversions. During the test, participants were instructed to look forward to occlude visual information about the stop platforms, and step down from A to land on B and C. They were then asked to make an absolute judgment regarding the ankle inversion they just experienced, by giving a number (1, 2, 3 or 4), without receiving feedback as to the correctness of the response. A total of 40 trials were completed, 10 for each inversion angle, presented in random order.

SPSS V.24 was used for data analysis, with p of <0.05 used to determine statistically significant results. Ankle proprioceptive discrimination sensitivity was determined by using the area under the receiver operating characteristic curve (AUC), applied in a pair-wise fashion to the stimulus-response matrix and providing a mean score reflecting the participant's ability to use proprioceptive information to discriminate between the 4 inversion angles. An AUC score of 1.0 reflects perfect

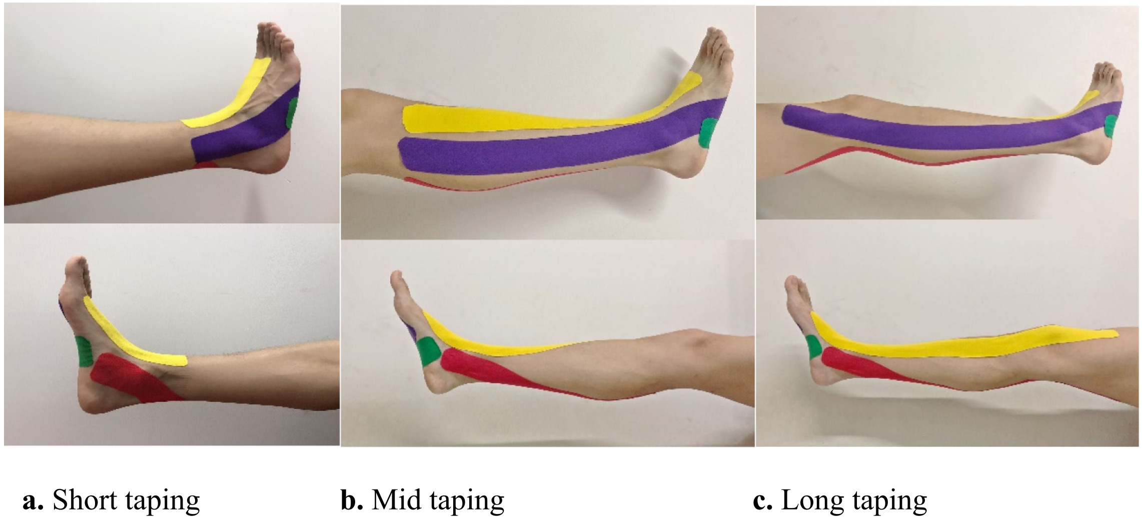

Fig. 1. The different ankle taping techniques. a. Short taping b. Mid taping c. Long taping.

discrimination between the four different ankle inversion angles, and a score of 0.5 is equivalent to chance responding, meaning that the participant cannot discriminate between the different ankle inversion angles.

To determine the effects of the different taping techniques on ankle proprioception, and any differences between the groups, a repeated measures ANOVA on the AUC scores was conducted. Paired sample *t*-tests were employed for post-hoc analysis, to examine differences between the testing conditions.

3. Results

Repeated measures ANOVA showed that AUC proprioceptive discrimination scores in individuals with CAI were significantly lower than in those without CAI (F = 8.196, $p = 0.008$), and that there was a significant KT main effect (F = 7.489, $p < 0.001$), suggesting that, overall, KT significantly improved ankle inversion proprioception in landing (Table 2). Polynomial trend analysis across the four testing conditions showed a significant linear effect (F = 17.083, p < 0.001), with no quadratic component (F = 1.735, $p = 0.198$) and no interaction effect (F = 0.220, $p = 0.642$), indicating that both groups improved their ankle proprioceptive performance in a similar linear fashion as KT tape length increased.

Post-hoc analysis showed that for the CAI group, both mid length ($p = 0.013$, 95%CI = −0.063, −0.009) and long length ($p = 0.010$, 95%CI = −0.067, −0.011) taping significantly improved ankle proprioceptive performance relative to no taping, with medium effect sizes (Cohen's d = 0.73 and 0.77, respectively) and that there was no difference between these two taping conditions ($p = 0.770$, 95% CI = −0.028, 0.021). For the non-CAI group, ankle proprioceptive discrimination sensitivity was significantly improved relative to no tape only with long length taping ($p = 0.007$, 95%CI = −0.080, −0.015, Cohen's d = 0.81) (Table 3 & Fig. 3).

Table 2
AUC scores with different KT tape length conditions in the CAI and non-CAI groups (Mean ± SD).

Group	N	Barefoot	Short taping	Mid taping	Long taping
CAI	15	0.764 ± 0.04	0.793 ± 0.05	0.800 ± 0.05	0.803 ± 0.04
Non-CAI	15	0.795 ± 0.05	0.814 ± 0.04	0.828 ± 0.04	0.842 ± 0.04
Total	30	0.779 ± 0.04	0.803 ± 0.05	0.814 ± 0.04	0.822 ± 0.04

AUC = area under the curve, CAI = chronic ankle instability, KT = Kinesiology taping, SD = standard deviation, N = number.

4. Discussion

The CAI main effect observed here indicated that, overall, individuals with CAI performed worse than those without CAI in ankle inversion

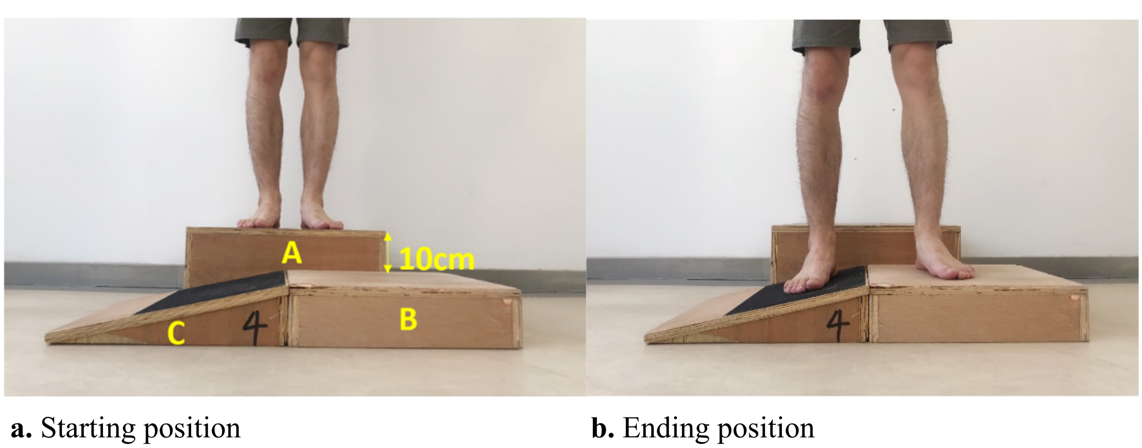

Fig. 2. Ankle inversion discrimination sensitivity assessed during landing. a. Starting position b. Ending position.

Table 3
Differences between barefoot and the three KT tape length conditions in the CAI and non-CAI groups.

Group	KT condition	p	95% CI	Cohen's d
CAI	Barefoot *vs* Short taping	0.057	−0.059, 0.001	0.54
	Barefoot *vs* Mid taping	0.013*	−0.063, −0.009	0.73
	Barefoot *vs* Long taping	0.010**	−0.067, −0.011	0.77
Non-CAI	Barefoot *vs* Short taping	0.200	−0.049, 0.011	0.35
	Barefoot *vs* Mid taping	0.055	−0.066, 0.001	0.54
	Barefoot *vs* Long taping	0.007**	−0.080, −0.015	0.81

KT = kinesiology taping, CAI = chronic ankle instability.
* $p < 0.05$.
** $p < 0.01$.

proprioceptive tests involving step-down landing. This result is consistent with our previous finding, where the AIDAL assessment was found to be reliable and able to discriminate between individuals with and without CAI.[16] However, there are studies that did not find ankle proprioceptive deficits in individuals with CAI.[18,19] One explanation for these conflicting findings is that the ecological validity of ankle proprioception tests may be important in determining if a test is sufficiently challenging to be sensitive, and that different tests may reflect testing posture specificity.[20] Previous studies have mainly used the psychophysical testing methods of threshold to detection of passive motion (TTDPM) and joint position reproduction (JPR) to obtain measures of proprioceptive performance, and both methods have a relative lack of ecological validity.[7] For example, Hubbard et al.[21] found that bracing decreased the ability of their participants to detect passive motion, as measured by testing their TTDPM. Moreover, Halseth et al.[22] concluded that KT did not appear to enhance proprioception in healthy individuals as determined by the JPR measure obtained in a non-weight-bearing posture. Thus TTDPM and JPR tests may be not sensitive enough to show the KT effect, or may produce differing results depending on the physical positioning of participants during the tests.

The AIDAL test employed here is an ecologically valid task, able to test ankle inversion proprioceptive discrimination ability during step-down landing. It involves full-weight-bearing, active movement, sufficient trials to estimate discrimination parameters, and testing at mid-range of ankle inversion.[16] This enables the AIDAL test to mimic the ‘action-at-injury’ with a functional movement. In addition, recent work has shown that results from different ankle proprioception tests are not correlated,[23] suggesting that different tests may tap into different neurophysiological aspects of proprioception. For example, recent research has shown that ankle proprioception measured by using the joint position reproduction method is related to current use of the ankle, while ankle proprioception measured by using the active movement extent discrimination apparatus is associated with ankle injury history.[24]

Our previous study has shown that the AIDAL had good to excellent test-retest reliability, and there was no significant learning effect between the first and second testing sessions in both non-CAI and CAI groups.[16] In addition, the 3 taping conditions were randomly assigned. Therefore, the effects observed here are more likely from KT, rather than repeated AIDAL testing. However, Witchalls et al.[25,26] found that compared to healthy participants, those with CAI showed a slower learning rate on the AMEDA proprioception task, in either a standing test, or a stepping forward movement. Future research is needed to explore whether KT can improve the proprioceptive learning rate in individuals with CAI.

The KT main effect observed here suggests that KT can improve ankle proprioception, irrespective of ankle instability status. However, the effect of KT varies in different groups with different lengths of taping. Specifically, for the CAI group, significant improvement in ankle proprioception was achieved at mid and long lengths of taping, while for the non-CAI group, only a long length of taping significantly improved ankle proprioception in landing. These findings suggest that CAI condition and length of taping do matter when considering KT as an intervention to improve proprioception in clinical practice.

KT may have produced additional cutaneous input that was then used to enhance ankle proprioceptive performance.[12,13] Simon et al.[27] hypothesized that proprioceptors are damaged after ankle injuries, and that afferent information is enhanced through the stimulation provided by KT, affecting the central nervous system (CNS) to form a new perceptual trace. Cho et al.[28] also proposed that the application of KT facilitates the transmission of proprioceptive information from joint structure to CNS, thus improving proprioception. The results from the current study extend the argument to suggest that KT works with individuals with physical deficits. For the CAI group with impaired ankle proprioception, short length KT taping was not effective in providing sufficient cutaneous input, whereas the mid and long lengths of taping achieved a similar effect in improving ankle proprioception.

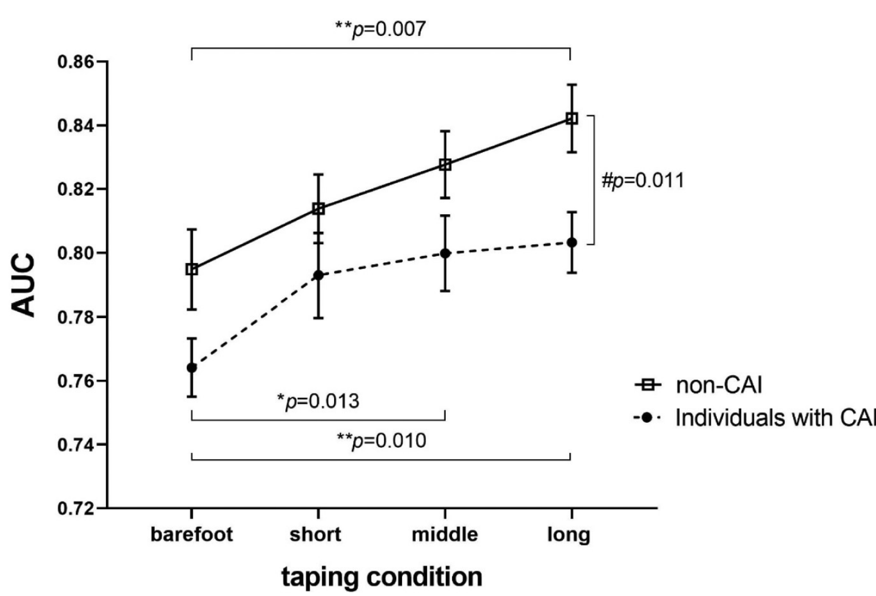

Fig. 3. Differences in ankle inversion discrimination tested in landing between individuals with CAI and non-CAI. Symbols indicate: * = $p < 0.05$ within groups, ** = $p < 0.01$ within groups, # = p < 0.05 between groups.

For individuals without CAI, only the longer length taping showed a statistically positive effect. This result was contrary to our hypothesis, as previous research has shown that KT may decrease ankle proprioception in individuals who already have superior ankle proprioception, measured in standing.[12] However, the current study showed that individuals without CAI who originally performed well on the AIDAL test could still benefit from KT if the taping was long enough to reach above the knee joint. In addition to the cutaneous input explanation mentioned above, there is another possible explanation for the significant effect of longer length taping improving ankle proprioception in the non-CAI group. Given that the long length of taping was across both the ankle and knee joints, it is possible that participants may have better used the multi-joint proprioceptive information from the ankle and knee to determine the ankle position and movement in space. Han et al.[29] argued that, from Sherrington's original concept of proprioception "*…perception of the position of the body, or body segments, in space*", it is sensible to explore how the brain perceives a joint position and movement during a multi-segment task. In the current case, when landing on a wedged platform, the knee and hip joint are naturally flexed. This is the way in which the brain normally receives information about ankle position and movement in sports and daily functional activities, as the joints involved in a multi-segment task do not function independently.[30] Therefore, the long length of taping above the knee joint may provide additional proprioceptive information from the knee for the brain to better integrate and determine degree of ankle inversion during landing.

An important implication from this study is that different KT lengths may affect ankle proprioceptive performance in different groups. This suggests that future studies may explore the effect of different length of taping on athletes from different sports and competing at different levels. In addition, compared to our ankle AMEDA proprioception assessment conducted in standing,[25] the AIDAL testing required participants to flex the knee during landing. Thus it would be useful to compare the impact of the long tape application on proprioception ability with an extended and a flexed knee.

There were some limitations in this study. First, the classification of short, mid and long length of taping was relatively arbitrary. Future studies may be needed to determine the taping length threshold sufficient to achieve a significant effect in both CAI and non-CAI individuals. Second, the amount of knee and hip flexion during landing was not strictly controlled. Future research may explore the effect of different landing squat depths on ankle inversion proprioception.

5. Conclusion

KT can be used to improve ankle inversion proprioceptive performance during landing in individuals both with and without CAI. However, variation in length of KT may have a different effect on each group. For individuals with CAI, mid to long length taping can improve ankle proprioception equally well, while for those without CAI, obtaining a significantly positive effect may require a long length of taping, extending to above the knee. These findings can inform the use of KT to improve proprioception in clinical practice and inform clinicians regarding the optimum taping length depending on CAI status.

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Declaration of interest

The authors declare no conflict in interest.

Confirmation of ethical compliance

The study was approved by the Shanghai University of Sport Ethics Committee (approval number 102772020RT011) and written informed consent was obtained from participants before data collection.

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