

Original Research

Influence of prophylactic ankle tapes on lower-extremity kinematics during a stop-jump task in chronic ankle instability

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Background and objective: Numerous tape applications have been used in patients with chronic ankle instability (CAI). However, the effect of prophylactic ankle taping on lower-extremity kinematics is still not well understood. This study aimed to investigate the effects of traditional taping, fibular repositioning taping, and kinesiology taping on the peak angles of the lower extremities in patients with CAI.

Materials and Methods: A total of 14 men (age, 24.07 ± 4.46 years; height, 175.06 ± 5.10 cm; weight, 82.24 ± 10.38 kg (mean \pm standard deviation)) with CAI identified using screening questionnaires (Cumberland Ankle Instability Tool, 17.64 ± 4.14 ; Foot and Ankle Ability Measure (FAAM) Activity of Daily Living, 86.69 ± 6.71 ; and FAAM Sports Subscale, 75.45 ± 6.70) participated. The peak angles of the hip, knee, and ankle joints during a stop-jump task, with and without tape application, were collected using a three-dimensional motion system.

Results: The following peak angles were measured: hip flexion, hip adduction (ADD), hip internal rotation (IR), knee flexion, knee abduction (ABD), knee IR, ankle dorsiflexion, ankle inversion, and ankle ADD. No significant differences were observed in the peak angle of each joint across conditions (hip flexion, $F_{(3,39)} = 0.85$, $p = 0.47$; hip ADD, $F_{(1.729,22.478)} = 1.90$, $p = 0.18$; hip IR, $F_{(1.632,21.220)} = 0.67$, $p = 0.49$; knee flexion, $F_{(3,39)} = 1.24$, $p = 0.15$; knee ABD, $F_{(1.691,21.982)} = 1.24$, $p = 0.30$; knee IR, $F_{(1.830,23.794)} = 0.44$, $p = 0.63$; ankle dorsiflexion, $F_{(3,39)} = 0.66$, $p = 0.58$; ankle inversion, $F_{(1.385,18.007)} = 0.85$, $p = 0.40$; ankle ADD, $F_{(1.865,24.249)} = 2.23$, $p = 0.13$).

Conclusion: The application of different taping techniques did not significantly change the peak joint angles of the lower extremities during a stop-jump task. These results contradict those of previous studies, suggesting that ankle taping restricts joint range of motion.

Keywords

Chronic ankle instability; Traditional taping; Fibular repositioning taping; Kinesiology taping; Lower-extremity kinematics; Stop-jump

1. Introduction

Lateral ankle sprain is the most frequent injury of the ankle that can occur in sports such as soccer, football, and bas-

ketball, as well as in activities of daily living (ADLs) [1, 2]. Repeated lateral ankle sprains after an acute injury may lead to chronic ankle instability (CAI) due to decreased muscle strength, proprioception, neuromuscular control, and re-

sponse rate [3, 4]. Eventually, CAI may increase the risk of post-traumatic osteoarthritis and articular degeneration of the ankle [2].

Athletes with CAI have been shown to have alterations of lower-extremity kinematics during dynamic movement tasks such as walking, running, and landing [5–8]. Previous studies reported that patients with CAI demonstrated limited dorsiflexion during gait [6] and increased inversion during downstairs walking [9]. This could result in a deficit in dynamic balance ability [10], which is possibly related to a recurrent ankle sprain [6] and may increase the risk of knee injury [11]. In addition, individuals with mechanical ankle instability have shown altered ankle kinematics with less sagittal plane displacement and greater frontal plane displacement during the stop-jump task than the functional ankle instability (FAI) group [12]. These features suggest increased ankle instability and a greater risk of injury [13]. Another study reported that patients with CAI showed a decreased knee flexion angle at initial contact (IC) during a landing task [7]. Decreased knee flexion angle during functional tasks could be a risk factor for noncontact knee joint injuries such as anterior cruciate ligament sprain [8]. One study reported that patients with CAI showed altered hip joint kinematics during a stop-jump task, such as increased hip flexion at IC and peak hip external rotation [5]. These hip joint kinematic changes lead to a burden on the ankle joint and cause iliotibial (IT) band injury and patellofemoral joint pain [14]. Therefore, athletes with CAI tend to use prophylactic ankle taping to provide a protective effect [15–18] and prevent recurrence by reducing mechanical laxity [15, 18].

Several prophylactic ankle taping techniques can be used to prevent the aforementioned negative characteristics in patients with CAI, such as traditional taping (TT), fibular repositioning taping (FRT), and kinesiology taping (KT). TT is considered to be effective in reducing the mechanical laxity of ligaments owing to its nonelastic material and multiple strips for the closed basket weaving method [19]. TT is mainly used in a closed basket weaving method designed to prevent inversion and plantar flexion, a mechanism that causes ankle sprains [20]. In a previous study, TT significantly restricted the movements of the ankle joint in the sagittal plane during drop landing in the healthy group [21]. TT can help neutralize the sagittal and frontal planes of the ankle in patients with CAI [22]. A previous study reported that TT affected the reduction of knee flexion but with no significant difference from the healthy group during drop landing [21]. FRT is known to be an effective prophylactic taping method because it is theorized to enhance postural control by correcting fibular malalignment in athletes with CAI [23]. Several studies have shown that the plantar flexion of patients with CAI using FRT decreased in the IC phase during drop landings, which means that FRT affected the stability of the ankle and reduced the risk of recurrence [23]. Moreover, FRT was effective in increasing dorsiflexion at maximum ankle angles in the sagittal plane [23]. However, the application of FRT to patients with CAI did not affect

the ankle, knee, and hip kinematics during gait in a previous study [24]. KT has therapeutic benefits, rather than external support, that activate the muscles by stimulating the tactile sensation by attaching it to the skin [25]. Additionally, a previous study reported that KT could reduce joint instability and pain [26]. Previous studies proposed that KT application positively affects the range of motion (ROM) of the ankle, knee, trunk, and other body segments [27–29]. When KT was applied to individuals with a neutral foot type, there were changes in the kinematics of the ankle and knee during running compared with those before the application of taping. In the toe-off phase, ankle plantar flexion decreased, and the knee angle increased [30]. Furthermore, ankle dorsiflexion increased in the IC phase [30]. If the kinematics in the ankle of CAI are changed, it is suggested that it will have a positive effect on the changes in the kinematics of the knee and hip joint [31]. Currently, there are studies examining the effects of FRT and KT on ankle kinematics, but studies examining the effects on knee and hip kinematics are insufficient. Since FRT and KT cause changes in the kinematics of the ankle [23, 28, 30], it is important to examine the knee and hip kinematics that can be altered by the kinetic chain. Therefore, we investigated the effect of FRT and KT on lower-extremity kinematics when applied to the ankle. Although various previous studies have reported the effect of prophylactic ankle taping in patients with CAI, limited information is available about the effects of taping on the lower-extremity kinematics of these patients. Therefore, this study aimed to investigate the effects of taping on the peak joint angles of the lower extremities in individuals with CAI. We hypothesized that each type of taping may have a positive effect on the lower-extremity kinematics of individuals with CAI during a stop-jump task.

2. Materials and methods

2.1 Participants

All physically active participants were recruited from the university and participated voluntarily. Before testing, all participants provided informed consent for their participation in the study. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of the Institutional Review Board of the university (2-10407099-AB-N-01-201906-HR-029-02). All documents were approved by the Institutional Review Board for the use and protection of human subjects. The Foot and Ankle Ability Measure Activity of Daily Living (FAAM-ADL), FAAM Sports Subscale (FAAM-SS), and Cumberland Ankle Instability Tool (CAIT) were used to identify the ankle status of the participants with CAI [32, 33]. The participants comprised 14 physically active men with CAI (age, 24.07 ± 4.46 years; height, 175.06 ± 5.10 cm; weight, 82.24 ± 10.38 kg; FAAM-ADL, 86.69 ± 6.71 ; FAAM-SS, 75.45 ± 6.70 ; CAIT, 17.64 ± 4.14 [mean \pm standard deviation]) (Table 1). The participant criteria were based on the International Ankle Consortium [34]. All participants experienced significant lateral ankle sprains at least once. The exclusion criteria were

as follows: acute ankle injury with swelling and/or bruising, history of injury and/or surgery in other lower-extremity joints, and ankle joint surgery within 6 weeks because of fracture and ligament rupture.

TABLE 1. Participants' demographics.

Characteristic	Mean \pm standard deviation
Age (years)	24.07 \pm 4.46
Height (cm)	175.06 \pm 5.10
Weight (kg)	82.24 \pm 10.38
FAAM-ADL	86.69 \pm 6.71
FAAM-SS	75.45 \pm 6.70
CAIT	17.64 \pm 4.14

FAAM-ADL, Foot and Ankle Ability Measure Activity of Daily Living; FAAM-SS, Foot and Ankle Ability Measure Sports Subscale; CAIT, Cumberland Ankle Instability Tool.

2.2 Procedures

We applied the three ankle tapings in participants with CAI and attempted to investigate the maximum angle during the first landing in the stop-jump task. Stop-jump movements are commonly seen in sports such as volleyball and basketball. The task is characterized by rapid deceleration, with the feet fixed on the ground and a change in vertical jumps [5].

When the participants arrived in the laboratory, they performed a 10-min walking task as a warm-up to prevent musculoskeletal injury. The order of application of the three different taping conditions (TT, FRT, and KT) was randomly assigned to each participant. All taping procedures were performed by a certified athletic trainer with extensive experience in taping to maintain the force applied to the taping of each participant. The taping conditions were applied on separate days with 24-h intervals under the supervision of a single clinician. Each participant practiced the stop-jump task three times during 1-h of taping adaptation and then performed the stop-jump task again. A flowchart is shown in Fig. 1. For data collection, reflective markers were placed bilaterally on the anterior superior iliac spine, posterior superior iliac spine, lateral midpoint of the femur, lateral epicondyle of the femur, lateral midpoint of the fibula, lateral malleolus, heel, and second metatarsophalangeal joint. The participants were instructed to run straight on a 5-m walkway at a maximum speed and land on a ground-embedded force plate (AMTI, Boston, USA) with the involved leg first. After landing on the force plate, the participants immediately performed a maximum vertical jump. When the knee flexion was at its maximum during the first landing, the peak angles of each lower-extremity joint were measured.

The peak angles of each joint of the lower extremity during the first landing with and without tape application were collected using a three-dimensional motion capture system (VICON, Oxford, England) at a 250-Hz sampling rate. The following variables were measured at the moment of the peak angle of the knee joint: hip flexion, hip adduction (ADD), hip internal rotation (IR), knee flexion, knee abduction (ABD), knee IR, ankle dorsiflexion, ankle inversion, and ankle ADD.

For data analysis, VICON Nexus software (Vicon Motion System, Ltd., Oxford, UK) was used to extract the kinematic and kinetic variables, and a customized LabVIEW code (version 2013; National Instruments Corp., Austin, TX, USA) was used to analyze the data.

2.3 Taping methods

2.3.1 Traditional taping

Zonas TT (Johnson & Johnson, Inc., New Brunswick, NJ, USA) was used in this study. We used a closed basket-weave taping technique. The participant held the ankle at 90° dorsiflexion. Two anchor strips were placed on the distal leg and around the foot. To prevent or protect inversion sprains, a stirrup strip was applied from the medial aspect of the leg and pulled under the heel to the lateral aspect of the leg. A horizontal "horseshoe" strip was placed from the medial to lateral aspect of the foot, followed by another stirrup in a weaving fashion. Thereafter, the leg was completely enclosed in horizontal strips. Figure-eight patterns and heel locks were applied to the medial and lateral aspects of the ankle in a single manner (Fig. 2) [35].

2.3.2 Fibular repositioning taping

In the seated position, each participant kept the ankle in a neutral position and underwent a standardized FRT using approximately 20 cm of Leukotape P® (BSN Inc., Charlotte, NC, USA). Q.D.A. Tape Adherent Spray (Q.D.A., Cramer Products, Inc., Gardner, KS, USA) was used for better adhesiveness. The strip was started 2 cm anterior to the fibula and 1 cm proximally to the tip of the lateral malleolus. It was applied obliquely around the lower leg and ended on the anterior aspect of the shin while applying the fibula glide (Fig. 3) [36].

2.3.3 Kinesiology taping

In this study, a 6 \times 25-cm strip of KT was utilized in accordance with Kase's KT manual [37]. The skin was shaved and cleaned before application. The participant was seated in a neutral ankle position. The strip was started with "0%" tension from approximately one-third of the leg on the lateral side toward the plantar aspect and along the fibula. Once it passed through the lateral malleolus, the tension was increased up to 50%, and the strip was applied under the heel and ankle to the medial side. Thereafter, the strip was passed around the anterolateral aspect of the ankle to the Achilles tendon. The strip was stretched up to 50%, while it passed over the lateral malleolus. The strip ended without tension on the dorsal aspect of the foot after surrounding the ankle (Fig. 4) [38].

2.4 Statistical procedures

The effects of the type of tape and time on lower-extremity peak kinematics were evaluated using three-factor (tape: TT, FRT, and KT) and two-factor (time: baseline and post) analyses of covariance. The pre-peak kinematic values were used as the covariates. When significant main effects of

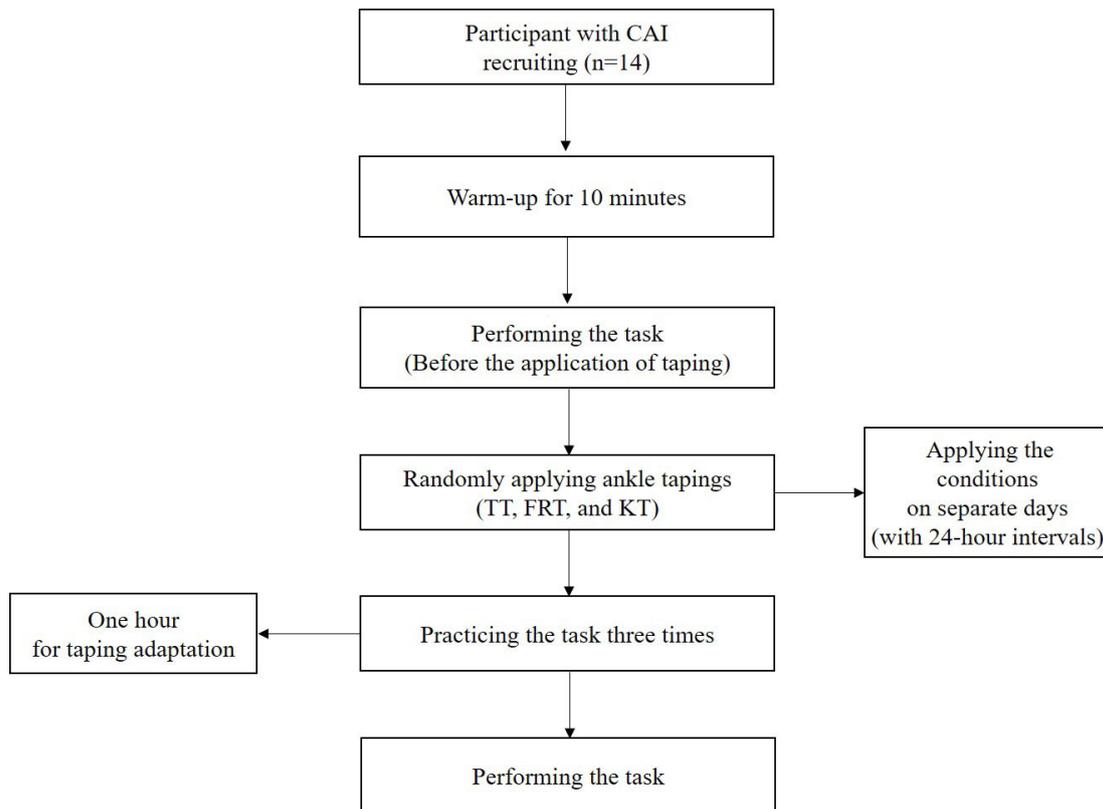


FIG. 1. A flowchart.

tape or time-by-tape interactions were detected, a Bonferroni post hoc test was employed to determine the sources of the differences. In addition, the effect size was calculated to compare the average difference between the baseline and after taping according to the taping application. Effect sizes by Cohen [39] were interpreted as follows: ≥ 0.8 , large; 0.5–0.79, moderate; 0.2–0.49, small; and < 0.2 , very small. Statistical analysis was conducted using SPSS (version 24.0 0; IBM SPSS Inc., Chicago, IL, USA) with the statistical significance level set a priori at $\alpha \leq 0.05$.

3. Results

3.1 Joint kinematics

The results for joint kinematics are presented in Table 2.

At the peak angle of the hip joint during the stop-jump task, the maximum hip flexion angle was not significantly different ($F_{(3,39)} = 0.85$, $p = 0.47$). Effect sizes for taping application during the task ranged from -0.18 to 0.25, which indicated very small to small decreases or increases in the hip flexion angle. The hip ADD angle ($F_{(1.729,22.478)} = 1.90$, $p = 0.18$) and hip IR angle ($F_{(1.632,21.220)} = 0.67$, $p = 0.49$) also showed no significant differences. Effect sizes ranged from -0.28 to 0.21, which indicated small decreases or increases in the hip ADD angle. For the hip IR angle, effect sizes ranged from -0.09 to 0.15, which indicated small decreases or increases.

At the peak angle of the knee joint during the stop-jump task, the maximum knee flexion angle was not significantly

different ($F_{(3,39)} = 1.24$, $p = 0.15$). Effect sizes ranged from -0.10 to 0.55, which indicated very small to medium decreases or increases in the knee flexion angle. The knee ABD angle ($F_{(1.691,21.982)} = 1.24$, $p = 0.30$) and IR angle ($F_{(1.830,23.794)} = 0.44$, $p = 0.63$) also showed no significant differences. Effect sizes ranged from -0.14 to 0.16, which indicated very small decreases or increases in the knee ABD angle. However, there was a very small or small increase in the knee IR angle, with the effect sizes of taping application during tasks ranging from 0.01 to 0.26.

At the peak angle of the ankle joint during the stop-jump task, the maximum ankle dorsiflexion angle was not significantly different ($F_{(3,39)} = 0.66$, $p = 0.58$). Effect sizes ranged from 0.01 to 0.30, which indicated very small increases in the ankle dorsiflexion angle. The ankle ADD angle ($F_{(1.865,24.249)} = 2.23$, $p = 0.13$) and inversion angle ($F_{(1.385,18.007)} = 0.85$, $p = 0.40$) also showed no significant differences. Effect sizes ranged from -0.56 to -0.11, which indicated decreases in the ankle ADD angle. For the ankle inversion angle, effect sizes ranged from -0.05 to 0.35, which indicated very small to small decreases or increases.

4. Discussion

The current study examined the effects of taping on the peak joint angles of the lower extremities in individuals with CAI during a stop-jump task. The results showed no statistically significant differences in the peak joint angles of the lower extremities, regardless of the applied tape. Therefore, the hypothesis of this study was not verified.

TABLE 2. Joint kinematics (mean ± SD).

Joint	Motion (°)	Taping	Baseline	Post-taping	Cohen's d effect size	F	p-value
Hip	Flexion	TT		66.93 ± 8.03	-0.04	F _(3,39) = 0.85	p = 0.47
		FRT	67.25 ± 8.98	65.95 ± 9.19	-0.18		
		KT		69.22 ± 6.35	0.25		
	Adduction	TT		-2.47 ± 3.57	0.21	F _(1.729,22.478) = 1.9	p = 0.18
		FRT	-3.26 ± 4.11	-4.61 ± 5.41	-0.28		
		KT		-3.93 ± 5.23	-0.14		
Knee	Internal rotation	TT		5.80 ± 11.69	-0.09	F _(1.632,21.220) = 0.67	p = 0.49
		FRT	6.88 ± 11.79	8.73 ± 12.95	0.15		
		KT		5.98 ± 13.39	-0.07		
	Flexion	TT		68.43 ± 4.92	0.55	F _(3,39) = 1.24	p = 0.15
		FRT	64.94 ± 7.45	64.09 ± 9.21	-0.10		
		KT		66.32 ± 6.50	0.20		
Ankle	Abduction	TT		5.13 ± 10.82	-0.14	F _(1.691,21.982) = 1.24	p = 0.30
		FRT	6.60 ± 9.62	8.18 ± 10.37	0.16		
		KT		6.55 ± 10.65	0.00		
	Internal rotation	TT		25.69 ± 13.39	0.26	F _(1.830,23.794) = 0.44	p = 0.63
		FRT	22.69 ± 9.69	22.78 ± 12.35	0.01		
		KT		23.15 ± 13.05	0.04		
Dorsiflexion	TT		9.22 ± 3.47	0.3	F _(3,39) = 0.66	p = 0.58	
	FRT	7.89 ± 5.17	7.95 ± 6.50	0.01			
	KT		9.06 ± 6.12	0.21			
Ankle	Adduction	TT		4.77 ± 13.85	-0.17	F _(1.865,24.249) = 2.23	p = 0.13
		FRT	6.83 ± 10.36	0.75 ± 11.3	-0.56		
		KT		5.76 ± 9.97	-0.11		
	Inversion	TT		-1.43 ± 2.90	0.05	F _(1.385,18.007) = 0.85	p = 0.40
		FRT	-1.55 ± 2.06	-0.82 ± 2.06	0.35		
		KT		-1.65 ± 2.07	-0.05		

Baseline, pre-taping; TT, traditional taping; FRT, fibular repositioning taping; KT, kinesiology taping.

4.1 Characteristics of functional tasks

Depending on the intensity of the task, ankle taping may influence the lower-extremity kinematics. The stop-jump task in this study could be considered a high-intensity exercise that includes running, jumping, and landing movements. One study found that the CAI group with ankle taping had reduced ankle dorsiflexion and inversion during low-intensity tasks [22], which was not observed in our study. Therefore, it could be speculated that the characteristics of the functional task utilized in this study may have influenced the lower-extremity kinematics. The large amount of energy absorbed in each of the lower extremities in high-intensity tasks may exceed the threshold of ankle taping compared with that in low-intensity tasks such as walking and jogging. In other words, high-intensity tasks require more ankle movement. In one study that applied TT and used both soft and stiff landing conditions, differences in energy absorption of the lower extremity during landing were observed between each joint [40]. The results indicated that the energy absorption of the ankle joint was relatively larger than that of the other joints under soft and stiff landing conditions. Accordingly, ankle taping may not influence lower-extremity kinematics because the energy absorption at the ankle joint is large during landing.

The lower-extremity kinematics of each joint are linked via a kinetic chain during sporting tasks [31]. A previous

study showed that less energy absorption in the ankle and knee joints resulted in large energy absorption in the hip joint in the CAI group compared with that in the control group in the eccentric phase during landing [31]. This could be explained by the fact that landing relies on the hip joint rather than on the ankle and knee joints [31]. In this study, the lack of change in ankle kinematics after ankle taping may not have altered the knee and hip kinematics according to the aforementioned lower-extremity kinetic chain.

4.2 Characteristics of ankle tapes

Generally, taping is known to be an external support that reduces ligament laxity [15], joint instability, and pain [41] and increases ROM by improving muscle activation [27, 29]. However, the results of the current study contradict those of previous studies [15, 27, 29, 41]. The characteristics of ankle tapings may have affected the results of the current study.

The TT and FRT used in the current study can be classified as rigid taping, while KT can be classified as elastic taping. One study compared the differences in peak muscle activation and peroneal latency during stability tests according to the characteristics of each type of taping [42]. The peroneus longus muscle activation of participants with FAI who underwent rigid taping was significantly larger than that of the participants from other groups (no-taping and KT groups) during a sudden inversion perturbation test [42].



FIG. 2. Traditional taping. The Zonas traditional tape (Johnson & Johnson Sports Medicine), a nonelastic tape, is utilized in accordance with a closed basket-weave taping technique in this study.

Furthermore, the peak muscle activation of the rigid-taping group increased during the static test (standing with a single limb) and dynamic stability test (two-footed vertical jumps), although the difference was not significant [42]. Moreover, the peroneal muscle latency was considerably longer in the rigid taping group during the dynamic test [42]. Similarly, in another study, the muscle activation of the healthy group subjected to rigid taping increased compared with that of the KT group during a sudden inversion perturbation test [43]. This result can be explained by the fact that rigid taping may pull the skin more than elastic taping, thus increasing muscle activation. Despite the use of rigid and elastic taping, the lack of change in lower-extremity kinematics in this study may be attributed to the characteristics of the aforementioned tasks.

TT, a rigid taping, may restrict the ankle ROM pre-exercise but not post-exercise because it can be loosened. A previous study showed that TT restricted the inversion to eversion and dorsiflexion to plantar-flexion angle compared with no-taping both pre- and post-exercise, despite tape loosening after the exercise [44]. Restricting the ankle ROM is a benefit of TT; however, it could also result in an increased risk of ankle injury because of tape loosening after some physical movements over time. This may explain why TT did not affect ankle kinematics in the CAI group in this study.

A previous study showed that the plantar flexion of the CAI group with FRT was reduced in the IC phase during



FIG. 3. Fibular repositioning taping. Leukotape P® (BSN Inc., Charlotte, NC, USA), a nonelastic tape, is utilized in this study. Q.D.A. Tape Adherent Spray (Q.D.A., Cramer Products, Inc., Gardner, KS 66030, USA) is used for better adhesiveness. It is applied obliquely around the lower leg and ended on the anterior aspect of the shin while applying the fibula glide.

landing tasks [23]. This means that FRT positively affects ankle kinematics and can decrease the risk of ankle sprain [23, 41]. However, the ankle kinematics of the CAI group with FRT did not change in the current study. In a previous study, participants with CAI who underwent FRT showed no significant increase in either dorsiflexion or dynamic balance during the Star Excursion Balance Test (SEBT) [45]. This demonstrated that FRT did not result in any changes in ankle kinematics during the functional task. This means that FRT does not seem to have the forces that can reposition the malaligned fibula during functional tasks such as the SEBT, unlike in gait. Participants with FRT experienced subjective improvements in confidence and stability during functional tasks [46].

In addition, the current study revealed that KT did not influence lower-extremity kinematics. KT, an elastic taping, has the benefit of increasing the joint ROM and activation of muscles by increasing the blood and lymphatic circulation by lifting the skin [25, 27, 28]. The principle of KT was disputed based on the results of the current study. In a previous study, KT did not positively affect functional performance in SEBT, but was an effective tool for improving participants' subjective improvement [47]. However, the CAI group with KT in the current study showed no significant differences during the stop-jump task. KT did not affect the activation



FIG. 4. Kinesiology taping. The kinesiology tape, an elastic tape, is utilized in accordance with Kase's KT manual in this study. The strip passes the lateral malleolus and is applied under the heel and ankle to the medial side. Then, it is passed around the anterolateral aspect of the ankle to the Achilles tendon. Finally, the strip is ended on the dorsal aspect of the foot after surrounding the ankle.

of the peroneus longus muscle in another study [43]. Based on these results, KT is not designed as an external support to restrict movement and increase muscle activation. Focusing on the effects of KT mentioned earlier, KT was applied to the CAI group, but no effect was observed. KT did not affect the ankle stability of muscles. Additionally, after 24–72 h of KT application to the vastus medialis origin to insertion, muscle activation was increased, and the peak torque value was maintained during isokinetic exercise; however, no effects were observed after 96 h. These effects continued after the removal of KT for 48 h [48]. However, as a result of performing the task 1 h after the taping application in this study, no significant clinical effects of KT were observed. In other words, the timing of KT application (before performing the task) may have influenced the findings of the current study. For these reasons, each joint with KT may not change according to the kinetic chain.

In summary, ankle taping seems to provide comfort and stability to the injured area by applying pressure to the skin; however, the effectiveness of taping is highly controversial. According to the current investigation, ankle taping seems to have a placebo effect, providing individuals with subjective feelings of confidence or stability rather than improving their functional performance ability. Consequently, the charac-

teristics of the specific tasks and types of ankle taping used in the current study may not have affected lower-extremity kinematics.

4.3 Movement changes on three planes

Although preventive ankle taping did not significantly affect lower-extremity kinematics, some changes were observed. TT caused lower-extremity kinematic changes in the sagittal plane, with increased ankle dorsiflexion and knee flexion and decreased hip flexion. It is suggested that TT has a slight effect on the improvement of the kinematics of the CAI during landing. However, FRT and KT resulted in increased ankle dorsiflexion, decreased knee flexion, and increased hip flexion. These kinematic changes are likely to cause injuries such as noncontact ACL injuries [7], PFP, and IT band injuries [14]. In other words, the application of FRT and KT was found to cause positive alterations in the distal joint and negative changes in the proximal joint. Among the three tapings, TT is considered to be effective in improving CAI when performing a task requiring sagittal movement. In addition, TT and FRT were found to have some effect in neutralizing the position of the ankle by reducing ankle inversion, but increased knee ABD [49] and hip ADD [50] were found to cause ACL injury mechanisms. Finally, the three ankle tapings caused a reduction in ankle ADD, one of the supination mechanisms of ankle sprains [51], but there was a risk of increasing noncontact ACL injury by increasing knee IR [52].

According to the changes in movement in these three planes, ankle taping had some local effect on the distal joint, but it was thought that it did not affect the proximal joints or rather increased the risk of injury to other joints.

4.4 Limitations of the study

The limitation of this study was the use of questionnaires such as the FAAM-ADL, FAAM-SS, and CAIT, which collect self-reported complaints of instability. In other words, the participants with CAI may not have had severe ankle instability and laxity of the ligaments. Moreover, it was difficult to compare the instability criteria of the ankle joints between the two groups and the kinematics of each joint because there was no healthy group considered as the control group in the current study. Therefore, objective measurement tools for evaluating ankle instability and physiological laxity of the ligaments, as well as a healthy group for comparison with the CAI group, are needed in the future. Although taping was applied to all participants in the same manner, the taping force applied to each participant may have been different because it is a manual method in the current study. In addition, the functional performance ability may be different between the dominant and nondominant limbs because the injured part may not be the dominant limb. Therefore, subjective questionnaires are needed to evaluate the functional performance ability between the dominant and nondominant limbs. Because the sample size in this study was too small, it was difficult to obtain significant results. Therefore, it is important to determine and perform an appropriate sample

size in the future. Finally, it is difficult to generalize that taping is not effective in all individuals with CAI because it was conducted only in young age groups in this study. Therefore, further research is needed to investigate the effect of taping on individuals with CAI in various age groups.

5. Conclusions

The application of taping to individuals with CAI has positive effects on reducing mechanical laxity, correcting abnormal alignment, and increasing muscle activation in the previous studies; however, this study showed that the application of taping does not affect the peak joint angles of the lower extremity during a stop-jump task. These results contradict those of previous studies, which suggested that ankle taping techniques result in restricted joint ROM. The tapings used in this study are thought to be effective during low-intensity exercises such as walking or jogging rather than high-intensity exercises such as running, jumping, and landing. In other words, taping should be applied according to the intensity of the exercise performed. Therefore, further investigations are needed to examine the influence of different prophylactic ankle taping techniques on minimizing ankle instability during high intensity, as well as sport performance and muscle activation.

Abbreviations

ABD, abduction; ADD, adduction; CAI, chronic ankle instability; CAIT, Cumberland Ankle Instability Tool; FAAM-ADL, Foot and Ankle Ability Measure Activity of Daily Living; FAAM-SS, Foot and Ankle Ability Measure Sports Subscale; FRT, fibular repositioning taping; IC, initial contact; IR, internal rotation; KT, kinesiology taping; ROM, range of motion; TT, traditional taping.

Author contributions

Conceptualization: HJ; Data curation: HJ; Formal analysis: HJ and EC; Methodology: HJ and EC; Project administration: HJ; Visualization: HJ, SC, and EC; Writing—original draft: HJ, SC, and EC; Writing—review and editing: HJ, SC, and EC. All authors have read and agreed to the published version of the manuscript.

Ethics approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of the Institutional Review Board of the university (2-10407099-AB-N-01-201906-HR-029-02). All documents were approved by the Institutional Review Board for the use and protection of human subjects.

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Conflict of interest

The authors declare no conflict of interest.

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