⟨ Clinical Research ⟩

The Effects of a Semi-Rigid Brace or Taping on Talocrural and Subtalar Kinematics in Chronic Ankle Instability

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Abstract: Background. *A semi-rigid brace or taping is often used to prevent giving-ways in the joint with chronic ankle instability (CAI). However, it remains unknown whether the application of a semi-rigid brace or taping modifies abnormal kinematics in CAI joints. The objective of this study was to determine if the application of a semi-rigid brace or taping of the ankle normalizes abnormal weight-bearing kinematics in CAI joints during ankle internal rotation in plantar flexion.* Methods. *A total of 14 male patients with unilateral CAI (mean age 21.1 ± 2.5 years) were enrolled. Three-dimensional bone models created from the computed tomography images were matched to the fluoroscopic images to compute the 6 degrees-of-freedom talocrural, subtalar, and ankle joint complex (AJC) kinematics for the healthy and contralateral CAI joints, as well as for CAI joints with a brace or taping. Selected outcome measures were talocrural anterior translation, talocrural internal rotation, and subtalar internal rotation.* Results. *There was no significant difference in talocrural anterior translation and internal rotation induced by applying either a semi-rigid brace or taping (*$P > .05$*). For subtalar internal rotation, there was a tendency toward restoration of normal kinematics in CAI joints after applying a semi-rigid brace or taping. However, the difference was not significant (*$P > .05$*).* Discussion. *Application of a semi-rigid brace or taping had limited effects on the CAI joint during weight-bearing ankle internal rotation in plantar flexion. Further studies using a variety of testing conditions should be conducted in the future.*

Levels of Evidence: *Therapeutic, Level IV—Cross-Sectional Case Series*

Keywords: chronic ankle instability; talocrural joint kinematics; subtalar joint kinematics; semi-rigid brace; taping

Lateral ankle sprain (LAS) is one of the most common injuries in sports and recreational activity.[1] According to earlier reports, 10% to 30% of all athletic injuries are ankle injuries, and ankle sprains comprise 70% or more of ankle injuries in many sports.[1] As LAS patients often return to sports without consulting a medical institution and receiving appropriate treatment, symptoms often persist.[2] Recurrence of ankle sprain is very high, with range of 56% to 74%,[3-5] and repeated LAS leads to

> "As CAI [chronic ankle instability] causes enormous economic and social costs, prevention of LAS [lateral ankle sprain] recurrence is an important issue."

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chronic ankle instability (CAI). Since CAI causes enormous economic and social costs, prevention of LAS recurrence is an important issue.

CAI is typically caused by mechanical ankle instability (MAI) and/or functional ankle instability (FAI).[6] Previously studied factors contributing to CAI have included "ligament laxity,"[7-9] "proprioceptive deficits,"[10-12] "neuromuscular deficits,"[13-15] "postural control deficits,"[16-18] and "muscle weakness,"[19-21] but the cause of CAI remains controversial. Furthermore, the association between CAI and abnormal kinematics has been examined. Based on a study using surface makers,[22,23] it was suggested that the CAI subject walks with the ankle in a inversion position compared to that in healthy subjects. A similar finding was shown during the side hop maneuver.[13] In addition, CAI joints demonstrated abnormal talocrural and subtalar joint kinematics in detailed 3-dimensional analytical studies.[24-26] Therefore, improvement of abnormal kinematics might contribute to the prevention of recurrent LAS.

Some previous studies have indicated that the external ankle support provided by bracing or taping is effective for preventing recurrent LAS.[27,28] The researchers considered that the reason for this effectiveness is that external ankle support contributes to improved neuromuscular control[29] or to proper grounding for the foot.[30,31] Recent 3-dimensional analysis suggested that LAS is caused by excessive ankle internal rotation in plantar flexion or dorsiflexion.[32-34] However, it is unclear whether external ankle support has any effect on joint kinematics during these movements. It is necessary to consider whether ankle joint kinematics during movements that are assumed to cause LAS can be normalized by the application of external ankle support for CAI joints.

The objective of this in vivo weight-bearing study was to determine whether the application of a semi-rigid brace or taping of the ankle can normalize the abnormal kinematics of CAI joints during ankle internal rotation in plantar flexion. We hypothesized that a semi-rigid brace or taping would contribute to restoring normal ankle kinematics in CAI joints.

Material and Methods

Subjects

This protocol was approved by the institutional review board of Yokohama Sports Medical Center prior to the initiation of the study. Subjects were recruited from Yokohama Sports Medical Center. Informed consent was obtained from all subjects prior to participation. Inclusion criteria for this study were (*a*) male gender, (*b*) a history of 2 or more unilateral LAS with no history of injury to the contralateral ankle, (*c*) no history of other medical or rheumatologic conditions, (*d*) at least 5 reported episodes of giving-way and a reported ongoing tendency for the previously injured ankle to give-way during sporting activities. Exclusion criteria were (*a*) LAS or giving-ways occurring in the preceding 6 weeks, (*b*) ankle swelling and/or pain occurring in the preceding 3 months, (*c*) a history of other lower extremity injury occurring in the preceding 3 months or with effects that persisted within the last 3 months, and (*d*) prior physical therapy treatment including balance exercises for the affected ankle. Fourteen male subjects with a mean age of 21.1 ± 2.5 years with unilateral CAI participated in this study (side of instability: right 10, left 4). The average period since the most recent LAS was 20.4 ± 12.1 months.

Stress Radiography

Stress radiographs of the bilateral talocrural joints were obtained for all subjects. Mechanical instability on stress radiographs was defined as the presence of greater than 3 mm translation on anterior drawer test or greater than 3° of talar tilt on stress test.[35] All radiographs were analyzed by one researcher.

Protocol

All subjects underwent a single weight-bearing fluoroscopy and computed tomography (CT) scan of the bilateral ankles to analyze the respective joint kinematics. Fluoroscopy measurements were obtained in the order of healthy joints (Healthy), CAI joints (CAI), semi-rigid brace for CAI joints (Brace), and taping for CAI joints (Tape). The semi-rigid brace ZAMST A2-DX (Nippon Sigmax Corp, Tokyo, Japan) used in this study consisted of nylon supporters and polyethylene guard and was designed to resist inversion/eversion and internal/external rotation loads while allowing dorsiflexion/plantar flexion (Figure 1). A novel taping technique was developed to stabilize the medial and lateral sides of the talocrural and subtalar joints using the elastic tape while allowing dorsiflexion/plantar flexion (Figure 2).

Figure 1.

A semi-rigid brace.

This brace was designed to resist inversion/eversion and internal/external rotation loads while allowing dorsiflexion/plantar flexion.

Fluoroscopy

Dynamic ankle motion was imaged using single-plane lateral fluoroscopy (Dyna Direct, Toshiba Medical Systems Corp, Tochigi, Japan). For each subject, motion sequences were recorded for both the ankle with CAI and the contralateral healthy joint. Fluoroscopy was performed with a sampling frequency of 7.5 Hz. An examiner instructed subjects on the testing

Figure 2.

A novel taping (Left, lateral view; Right, medial view).

This technique was developed to stabilize the medial and lateral sides of the talocrural and subtalar joints while allowing dorsiflexion/plantar flexion. It consisted of elastic (brown) and nonelastic (white) tape.

procedures and measured ankle positions, and subjects performed a warm-up routine prior to data collection. During fluoroscopic imaging, subjects stood in a lunge position with the forward foot fixed on a tilted footplate mounted on a custom automated turntable. At the measurement, subjects completed 3 cycles of foot internal–external rotation within 10 seconds. Specially designed footplates were used to collect data with the ankle positioned in 20° plantar flexion. Prior to data collection, equal distribution of body weight between the 2 lower extremities was confirmed using a scale. During testing, the turntable alternately rotated at a constant speed (20 rpm) within an arc determined by a preset resisting torque (10 N m) so that images were obtained as the ankle cycled passively through 2 internal and external rotations.[26]

CT Images and Geometric Bone Models

For all subjects, non-weight-bearing CT images were obtained from both lower extremities (Zomatom plus-4 VZ, Siemens, Munich, Germany) at a 1.0 mm slice pitch, perpendicular to the longitudinal axis of the hindfood, spanning the area from the distal 100 mm of the tibial plafond to the distal extent of the calcaneus. During scanning, the ankle was held at 0° dorsiflexion without applying controlling the horizontal or frontal rotations. Geometric bone models of the ankle mortise, talus, and calcaneus were then created from these CT images for each patient. Exterior cortical bone edges in the images were segmented using commercial software (3D-Doctor, Able Software, Lexington, MA), and these point clouds were converted into polygonal surface models.[25,26,36] Anatomic coordinate systems were then embedded in each bone model using a previously described method and custom software (VH KneeFitter).[25,26,36]

3D-to-2D Registration Technique

Six degrees-of-freedom in vivo positions and orientations of the ankle mortise, talus, and calcaneus were determined using a published 3D-to-2D registration technique and custom JointTrack software.[36,37] According to the previously published technique, fluoroscopic images were manually matched with the geometric bone models followed by automated matching using a nonlinear least-squares technique.[37,38] Kinematics were determined from the 6 degrees-of-freedom positions and orientations of each bone model using Cardan angles.[39]

Outcome Measures

Kinematics of the talocrural joint, the subtalar joint, and the ankle joint complex (AJC) were expressed as the motion of the talar origin relative to the tibial coordinate system, the motion of the calcaneal origin relative to the talar coordinate system, and the motion of the calcaneal origin relative to the tibial coordinate system, respectively. Inversion–eversion was defined by rotation around the anteroposterior axis, internal–external rotation was defined by rotation around the superoinferior axis, and plantar flexion–dorsiflexion was defined by rotation around the mediolateral axis. Selected outcome measures were talocrural anterior translation, talocrural internal rotation, and subtalar internal rotation, which had each demonstrated significant differences between healthy and CAI joints in our previous study.[26] Therefore, this study compared talocrural anterior translation, talocrural internal rotation, and subtalar internal rotation among Healthy, CAI, Brace, and Tape. Kinematics was compared between the CAI and healthy joints from 7° AJC external rotation to 7° AJC internal rotation, where the joint position on the healthy side while standing was set at 0° AJC rotation.[26]

Statistical Analysis

Kruskal–Wallis test was used to compare joint kinematics between the 4 groups (Healthy, CAI, Brace, Tape), and Tukey–Kramer test was used as a post hoc test. All data were analyzed using the Statistical Program for the Social Sciences software package (PASW Statistics 18, SPSS Inc, Chicago, IL). Differences were considered significant at $P < .05$.

Results

Stress Radiography

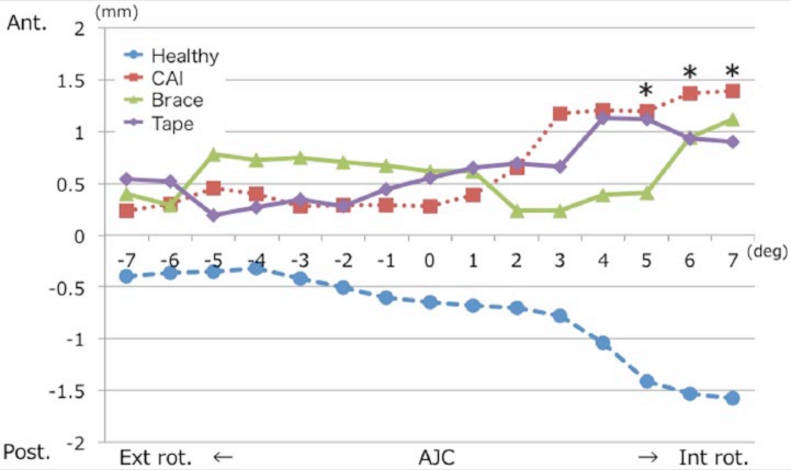
Three subjects demonstrated mechanical instability of the talocrural joint (anterior drawer 1, talar tilt 2), whereas the remaining subjects did not.

Joint Kinematics

In the talocrural joint kinematics, although significant differences were detected between Healthy and other groups during ankle internal rotation in plantar flexion ($P < .05$), there was no significant difference in anterior translation or internal rotation following application of a semi-rigid brace or taping ($P > .05$; Figures 3 and 4). In the subtalar joint kinematics, a tendency toward restoration of normal kinematics in the CAI joints was observed in Brace and Tape. However, the difference was not significant ($P > .05$; Figure 5).

Figure 3.

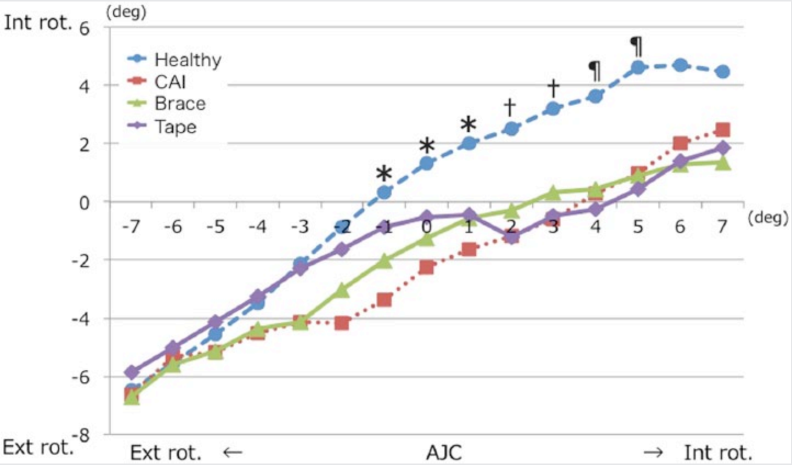
Talocrural anterior translation during ankle internal rotation in plantar flexion.



The results in the graphs represent average values. There was no significant difference after application of a semi-rigid brace or taping.
Abbreviations: Ant., anterior translation; Post., posterior translation; Int rot., internal rotation; Ext rot., external rotation; AJC, ankle joint complex.
*Significant difference between CAI and Healthy ($P < .05$).

Figure 4.

Talocrural internal rotation during ankle internal rotation in plantar flexion.



The results in the graphs represent average values. There was no significant difference after application of a semi-rigid brace or taping.
Abbreviations: Int rot., internal rotation; Ext rot., external rotation; AJC, ankle joint complex.
*Significant difference between Healthy and CAI ($P < .05$); ¶Significant difference between Healthy and CAI or Brace ($P < .05$); †Significant difference between Healthy and other groups ($P < .05$).

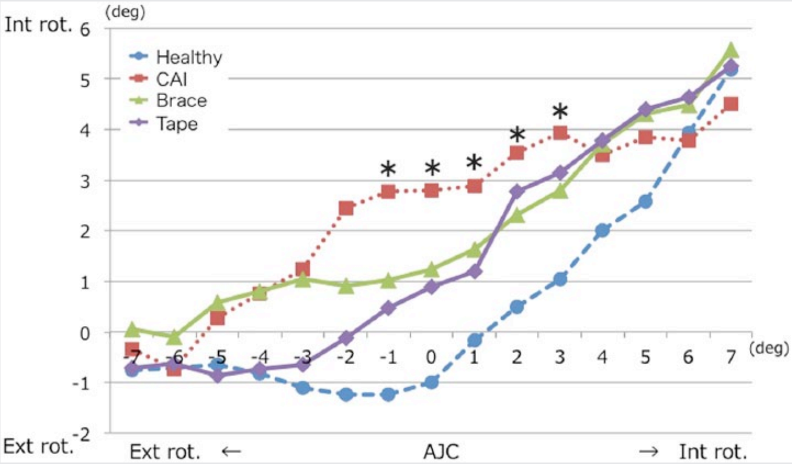
Discussion

The objective of this study was to determine whether the application of a semi-rigid brace or taping of the ankle would normalize kinematics in CAI joints. During ankle internal rotation in plantar flexion, there was no significant restoration of normal kinematics in the CAI joints following the application of a semi-rigid brace or taping.

It was previously reported that external ankle supports effectively prevent recurrent LAS[27,40] by improving neuromuscular control, which was damaged by LAS.[29] In contrast, negative results have been shown in subjects without previous LAS.[27,41,42] Therefore, normalization of abnormal joint kinematics is necessary to prevent initial LAS. Many studies have indicated that external ankle supports could restrict ankle inversion/eversion range of motion or kinematics.[43-50] However, some studies reported that external ankle support limits mechanically imposed ankle inversion stress when the ankle is in the position in which LAS occurs.[28,43,50] Thus, consensus has not yet been achieved. In addition, these studies did not evaluate the dynamic kinematics of the talocrural and subtalar joints separately. Therefore, modification of joint kinematics following application of external ankle supports needs to be evaluated by detailed measurements of talocrural and subtalar joint movements in the foot position assumed to cause LAS.

Figure 5.

Subtalar internal rotation during ankle internal rotation in plantar flexion.



The results in the graphs represent average values. There was no significant difference after application of a semi-rigid brace or taping.

Abbreviations: Int rot., internal rotation; Ext rot., external rotation; AJC, ankle joint complex.

*Significant difference between CAI and Healthy ($P < .05$).

To our knowledge, this is the first study to consider the effects of external ankle support on talocrural and subtalar joints kinematics using the 3D-to-2D registration technique. During weight-bearing ankle internal rotation in plantar flexion, subtalar internal rotation tended to approach that of healthy joints following application of a semi-rigid brace or taping as suggested by previous studies,[40,51] but there was no significant difference between Brace or Tape and CAI. In contrast, there were poor effects on the talocrural joint in this study. This may be because the range of ankle motion tested in our study had much smaller torque and slower speed compared with those of ankle motion during LAS. It may be possible to obtain a beneficial effect during motion closer to that occurring during LAS.

The 3D-to-2D registration technique using single-plane lateral fluoroscopy or radiography is a well-established technique to measure dynamic weight-bearing knee kinematics in vivo with standard errors within 0.53 mm for translations and 0.54° for rotations.[38] All subjects demonstrated a unilateral CAI based on questionnaire responses. In addition, fitting of the brace and taping were performed by a single physical therapist. Moreover, there were no significant differences in AJC plantar flexion angles. Accordingly, we consider that this study was carried out with high internal validity. As for the external validity, since this study examined young, healthy males who did not have osteoarthritis, these findings may not be applicable to females or elderly people with osteoarthritis. Furthermore, the results may differ when another type of brace or taping is applied.

In this study, torque and speed of the tested ankle motion were smaller and slower, respectively, than those of ankle motion during LAS. Although the amount of load during measurement was controlled to exactly half of the body weight using a scale, we cannot rule out the possibility of an error in the amount of weight-bearing during imaging procedures. Additionally, although all subjects demonstrated evidence of MAI on stress radiography, we did not confirm the ligament condition by magnetic resonance imaging or computed tomography.

During ankle internal rotation in plantar flexion, there was no apparent restoration of normal kinematics in the CAI joints after application of a semi-rigid brace or taping. This finding indicated that the effects of a semi-rigid brace or taping on CAI joints during ankle weight-bearing rotation were limited. This information will be useful in improving brace design and taping technique. However, further detailed studies that observe the effects of various types of external supports on talocrural and subtalar joint kinematics during movements that more closely approximate those that occur during LAS are needed.

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