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Biomechanical Comparison of 3 Ankle Braces With and Without Free Rotation in the Sagittal Plane

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Context: Various designs of braces including hinged and nonhinged models are used to provide external support of the ankle. Hinged ankle braces supposedly allow almost free dorsiflexion and plantar flexion of the foot in the sagittal plane. It is unclear, however, whether this additional degree of freedom affects the stabilizing effect of the brace in the other planes of motion.

Objective: To investigate the dynamic and passive stabilizing effects of 3 ankle braces, 2 hinged models that provide free plantar flexion–dorsiflexion in the sagittal plane and 1 ankle brace without a hinge.

Design: Crossover study.

Setting: University Movement Analysis Laboratory.

Patients or Other Participants: Seventeen healthy volunteers (5 women, 12 men; age = 25.4 ± 4.8 years; height = 180.3 ± 6.5 cm; body mass = 75.5 ± 10.4 kg).

Intervention(s): We dynamically induced foot inversion on a tilting platform and passively induced foot movements in 6 directions via a custom-built apparatus in 3 brace conditions and a control condition (no brace).

Main Outcome Measure(s): Maximum inversion was determined dynamically using an in-shoe electrogoniometer. Passively induced maximal joint angles were measured using a torque and angle sensor. We analyzed differences among the 4 ankle-brace conditions (3 braces, 1 control) for each of the dependent variables with Friedman and post hoc tests ($P < .05$).

Results: Each ankle brace restricted dynamic foot-inversion movements on the tilting platform as compared with the control condition, whereas only the 2 hinged ankle braces differed from each other, with greater movement restriction caused by the Ankle X model. Passive foot inversion was reduced with all ankle braces. Passive plantar flexion was greater in the hinged models as compared with the nonhinged brace.

Conclusions: All ankle braces showed stabilizing effects against dynamic and passive foot inversion. Differences between the hinged braces and the nonhinged brace did not appear to be clinically relevant.

Key Words: ankle–foot complex, inversion, joint motion, ankle stabilization

Key Points

- Both the hinged and nonhinged braces appeared to sufficiently restrict dynamically and passively induced foot inversion.
- Other than the existence of a hinge, factors related to brace design, material, or application seemed to be responsible for differences in movement restriction.
- The Ankle X brace provided the greatest amount of restriction against dynamic inversion.

With a prevalence of 20%, ankle sprains are the most frequent injuries in athletes and often happen during running and jumping activities,[1] most often during direct contact with an opponent.[2] Taping and ankle braces are the most advocated interventions to prevent ankle injuries.[1,3–8] Braces differ in design, material, and movement restriction of the ankle-foot joint–complex (eg, semirigid and lace-up braces)[9–11]; the goals are to provide sufficient protection but also sufficient flexibility of the ankle during sports and activities of daily living. Consequently, the stabilizing effects of braces need to be evaluated.[12] Semirigid braces use a stirrup design consisting of a thermoplastic material[13] and are recommended for dynamic conditions, eg, sports, in which the primary goal is to restrict foot inversion but not plantar flexion and dorsiflexion.[10] Therefore, among the semirigid brace models, hinged braces have been designed to allow free rotation in the sagittal plane for almost the entire range of dorsiflexion and plantar flexion of the ankle. However, soft and semirigid braces that allow more plantar flexion were associated with greater inversion velocity on a tilting platform as well as greater amplitude of passively induced inversion.[10] Furthermore, wearing an ankle brace with a subtalar locking system was notably effective in limiting foot inversion during passive as well as dynamic inversion compared with a functional hinged brace and a lace-up brace.[14] Therefore, less-restricted plantar flexion may imply less stabilization in associated foot displacement because it is related to some degree to hindfoot inversion.[15]

Rapidly induced inversion movements are usually evaluated with tilting platforms or trapdoor mechanisms and may provide information about the stabilizing effect of ankle braces under dynamic loading conditions that simulate inversion trauma.[10,16–18] Passive testing usually involves the application of an external force or moment to the ankle-foot joint–complex so that the stabilizing effect of ankle bracing in other movement directions (plantar flexion, dorsiflexion, eversion, external and internal rotation) can be assessed. These directions are also considered relevant in the evaluation of ankle braces.[10,19] This method does not represent the actual injury mechanism because it lacks the dynamic load application of a real-life trauma situation.[10] However, a high correlation ($r = 0.78$; $P = .0031$) was reported[10] between dynamically and passively induced inversion, thus confirming that both methods provide information about various aspects of the stabilizing effects of ankle braces.

The aim of our study was to compare the stabilizing effects of 3 ankle braces: 2 hinged models with free rotation in the sagittal plane (Body Armor Embrace [DARCO (Europe) GmbH, Raisting, Germany] and Ankle X [McDavid, Woodridge, IL]) and 1 model without free rotation in the sagittal plane (Aircast AirGo [DJO LLC, Vista, CA]), during a rapidly induced foot-inversion movement on a tilting platform, as well as during passively induced movements in 3 anatomical planes (6 directions) of the ankle-foot joint–complex. We hypothesized that all ankle braces would restrict ankle movements during rapidly induced inversion and passively induced movements of the ankle compared with the unbraced condition. Furthermore, we hypothesized that the hinged braces would provide less stabilization during a rapidly induced inversion and result in larger joint angles during passively induced movements of the ankle and foot compared with the unhinged brace.

METHODS

Participants and Setting

We recruited 17 healthy participants (5 women, 12 men) for this biomechanical study in a laboratory setting. Their mean age was 25.4 $\pm$ 4.8 years, height was 180.3 $\pm$ 6.5 cm, and body mass was 75.5 $\pm$ 10.4 kg. Specific inclusion criteria were experience in sports requiring running or jumping and regular athletic activity during the week. Exclusion criteria were a history of ankle injury within 6 months of the investigation or any other orthopaedic or neurologic condition that could influence ankle and foot mechanics and joint movement. We estimated sample size based on the results of pilot measurements and found that 17 participants would be needed to detect a 3° difference in the joint angles among the 4 measurements with a probability of $1 - \beta = .80$ at a significance level of .05. The study was reviewed and approved by the local ethics committee. After we informed the participants about the aims and procedures of the study, they gave written consent.

Testing Procedures

Ankle Braces. We tested 3 commercially available braces and the control condition using a within-subjects crossover design. The first brace was the Aircast AirGo, which incorporates a semirigid shell and foam-filled air cells to protect the ankle (Figure 1). It includes a crossing strap to protect the anterior talofibular ligament. The manufacturer recommends this ankle brace for preventing ankle sprains and for therapy of acute mild ankle sprains as well as chronic instability. The second brace was the hinged DARCO Body Armor Embrace, which the manufacturer recommends be used in preventing ankle sprains during sports activities, after acute ankle injury, and during rehabilitation. The ankle is supported by 2 polypropylene shells, which are connected by a plastic stirrup at both sides of the ankle and a shell underneath the heel. A crossing strap is used to prevent or limit talar shift and to protect the anterior talofibular ligament. The third brace was the McDavid Ankle X: according to the manufacturer, this is designed to treat and prevent ankle sprains and instabilities, as well as for injury prevention in sports and other activities. The brace consists of a neoprene sock, and the ankle is supported by a flexible hinged outer cast that is tightened by a hook-and-loop strap. The hinged ankle braces should allow almost free plantar-flexion and dorsiflexion movement to avoid constraining sport-specific movements. All braces were available in sizes small, medium, and large. We determined each person's size by having him or her wear the braces during walking, stair climbing, and hopping before data collection and then selecting the best-fitting size. The braces were applied and fastened according to the manufacturer's instructions. The investigator ensured a tight but comfortable fit and fixation of the braces and shoes. All participants wore the same shoe model (Cross Training XT; Nike Inc, Beaverton, OR) for the testing procedures.

Ankle-Foot Joint–Complex Testing

We evaluated the maximal joint angles of the foot for the 3 ankle braces and compared them with a control (unbraced) condition using 2 protocols: the first induced a rapid dynamic-inversion movement (dynamic testing), whereas the second induced a passive motion in all movement directions of the ankle-foot joint–complex (passive testing).

Testing the Stabilization Effect of the Ankle Braces During Dynamic Foot Inversion. In the first protocol, the examiner induced an unexpected unilateral foot inversion in the loaded stance on a tilting platform with an angle of 30°[10,20] with and without a brace (Figure 2). The independent variable was test condition with 4 levels: control, the nonhinged AirGo, the hinged Embrace, and the hinged Ankle X. The dependent variable was maximal inversion angle. The tilting platform was a trapdoor with a mechanical release that the examiner triggered; the participant was blinded to the timing of the trapdoor release.[10,21] The inversion movement was measured with a customized electromechanical in-shoe goniometer, which fit inside the shoe beneath the ankle brace in the brace conditions (Figure 2). The examiner applied a 2-mm plastic heel counter at the posterior part of the heel and fixed it with an elastic strap. A U-shaped aluminum rod was fixed to the heel counter. To transfer the hindfoot-inversion movement in the shoe to the outside and to measure the angle between the heel and the shank, we combined a potentiometer with a flexible plastic rod and fixed it at the aluminum rod in alignment with the subtalar joint axis of rotation, where most of the eversion–inversion movement occurs.[22] Strong test-retest reliability ($r = 0.82$), along with a high correlation between dynamic and passive inversion ($r = 0.78$) and a significantly lower coefficient of variability compared with an external goniometer was previously found[10,23] for the in-shoe goniometer. Increased inversion

Figure 1. The 3 different ankle braces. A, Aircast AirGo (DJO LLC, Vista, CA) without free rotation in sagittal plane; B, Body Armor Embrace (DARCO [Europe] GmbH, Raisting, Germany) with free rotation; and C, Ankle X (McDavid, Woodridge, IL) with free rotation. All braces are available in small, medium, and large sizes.

due to a "creeping" effect of the ligaments of about 7% or 2° has been reported[24] when trials of active and passive testing are repeated. Consequently, a difference of 3° would be clinically relevant, given 35° to 40° as the previously reported value for active and passive inversion.[10,11,17,19] Participants did not wear socks while on the tilting platform to avoid sliding of the calcaneus in the plastic heel counter of the in-shoe goniometer and to enhance accuracy of data. Each participant completed 5 trials with all 4 ankle braces; these data were recorded and stored for further analyses. The order of the ankle-brace application was randomized for each participant to avoid any effects of fatigue or habituation.

Testing the Stabilization Effect of Ankle Braces During Passively Induced Foot Movements. In the second protocol directly following dynamic testing, we evaluated passive foot and ankle movements (inversion, eversion, dorsiflexion, plantar flexion, internal and external rotation) with a custom-built fixture[10] (Figure 3). The independent variable was again ankle-brace condition with 4 levels: control, the nonhinged AirGo, the hinged Embrace, and the hinged Ankle X. The dependent variables were maximal angles of (1) inversion, (2) eversion, (3) plantar flexion, (4) dorsiflexion, (5) internal rotation, and (6) external rotation. The participant lay supine on a treatment bench. The examiner fixed the shank in the device and placed the foot on a flexible platform in neutral; for each participant, the position was identical and controlled by a locking system. The whole ankle-foot joint–complex was passively moved in the 3 anatomical planes (frontal plane: eversion and inversion; sagittal plane: plantar flexion and dorsiflexion; transversal plane: internal and external rotation) that are usually involved to various extents in the injury mechanism of ankle sprains. The rotation axis for eversion–inversion conformed to the longitudinal axis of the foot for talocrural plantar flexion–dorsiflexion to the intermalleolar axis, and for internal–external rotation to the longitudinal axis of the tibia, as recommended by the International Society of Biomechanics.[22] The flexible platform was adjustable so that the alignment of anatomical axis could be reliably positioned for each participant. The locking system ensured

Figure 2. Simulation of an ankle sprain (foot inversion) on the tilting platform (30° tilting dislocation) measured with the in-shoe goniometer system. The left leg and foot are fully loaded. Here, the braced condition is illustrated.

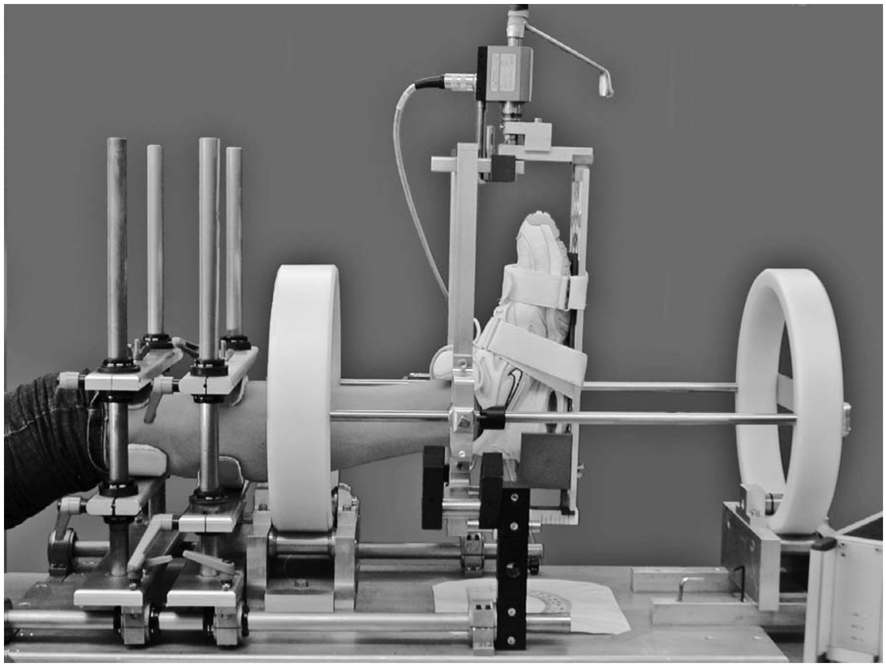


Figure 3. Apparatus for the measurement of maximal joint angles in 3 movement planes (6 directions) with an induced torque of 9 and 12 Nm only for dorsiflexion. Here, the unbraced condition is illustrated.

identical repositioning of the foot for each participant. Maximal angles for each movement were recorded at a defined torque (12 Nm for dorsiflexion, 9 Nm for the other movements). Angles and torques were measured with a torque sensor with a rotating measuring shaft (Mini-Smart Torque Sensor 0170 MS; Staiger Mohilo & Co GmbH, Lorch, Germany). We recorded dorsiflexion at 12 Nm because passive resistance (stiffness) caused by muscles with a greater cross-sectional area (in this case, the triceps surae muscle) is greater than for muscles with a smaller cross-sectional area (in this case, the tibialis anterior or peroneus longus muscle).[25] In pilot measurements, we found these torques reached the limits of comfort in the ankle movements. In a previous study[10] using the same device, mean torques ranged from 4.9 $\pm$ 1.9 Nm for internal rotation to 10.7 $\pm$ 3.5 Nm for dorsiflexion. Nigg et al[24] used a torque of 10 Nm to passively invert the foot. In each condition, 3 valid trials for each movement direction were recorded about 1 minute after the participant performed 1 pilot trial for familiarization with the movement. After each trial, the examiner repositioned the foot in neutral again if necessary and reset the torque sensor. For practical reasons (ie, platform configuration), we measured only the left foot in both dynamic and passive testing. The left foot was chosen arbitrarily before the study began. We did not take into account whether this was the dominant or nondominant leg because no leg-dominance effect was observed for peroneal reflex latencies in healthy participants during sudden inversion on a tilting platform.[21] For statistical analysis, the average of 5 trials of maximum inversion angle was used. For passive testing, the average of 3 trials of maximum angles of the 6 directions was recorded at the defined torque.

Instrumentation

The electrical signal of the goniometer was recorded with the Noraxon 2000 system (Noraxon USA Inc, Scottsdale, AZ) with a sampling frequency of 1000 Hz and then filtered with a low-pass finite impulse response filter. The optimal cutoff frequency of 20 Hz was estimated under visual control compared with the unfiltered signal. For the 5 repeated trials, inversion angles on the tilting platform were determined for each participant and each brace condition at the beginning of platform tilting, at the end of platform tilting (inversion at 30° of platform tilting), and in the first 100 milliseconds after the end of platform tilting (maximum inversion angle).

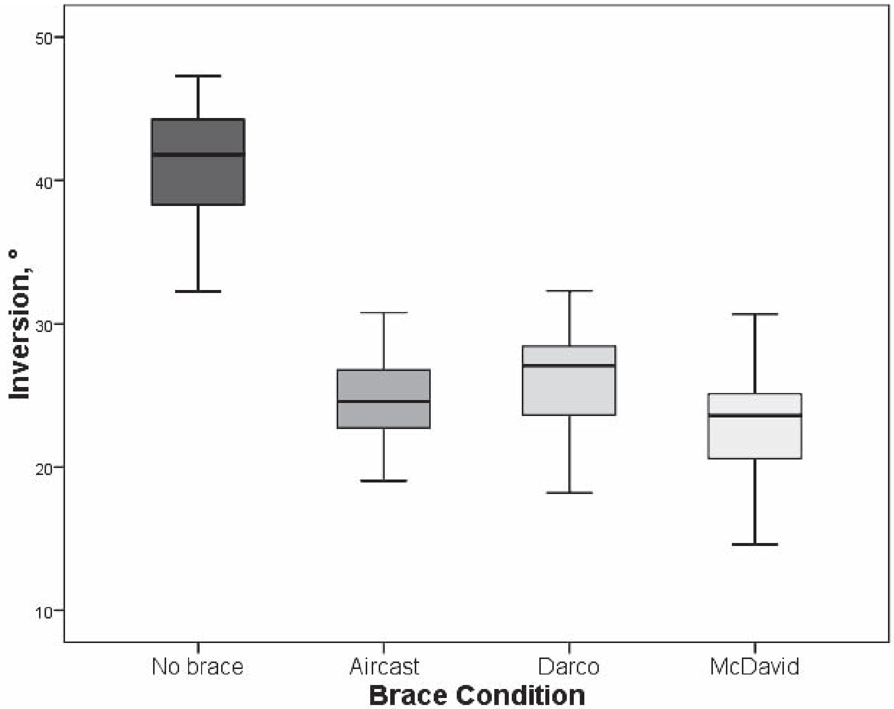
Statistical Analysis

After testing data for normal distribution, we confirmed the nonparametric data distribution with the Kolmogorov–Smirnov test and histograms. Therefore, we performed Friedman tests for paired data to determine differences among all brace conditions and the control condition. Wilcoxon signed rank tests were conducted post hoc to detect which conditions differed statistically. The global significance level was set to $P < .05$. The Bonferroni correction was applied to adjust for multiple tests. Therefore, the local significance limit was set to $P < .05/6 = .0083$. We used the Spearman ρ to determine the correlation between the inversion on the tilting platform and passive inversion. Statistical analyses were performed using SPSS (version 21 for Windows; IBM Corporation, Somers, NY).

RESULTS

Dynamic Foot Inversion

The 3 brace models limited foot inversion during a sudden inversion compared with the unbraced condition ($P < .001$; Figures 4 and 5, Table). We found a difference in the maximum inversion angle on the tilting platform



Condition	Maximal Inversion, °				
	Minimum	25% Quartile	Median	75% Quartile	Maximum
Unbraced	**32.2**	**37.9**	**41.8**	**44.4**	**47.3**
Aircast AirGo	**19.0**	**22.7**	**24.6**	**26.9**	**30.8**
DARCO Body Armor Embrace	**18.2**	**23.0**	**27.1**	**28.5**	**32.3**
McDavid Ankle X	**14.6**	**20.0**	**23.6**	**25.5**	**30.7**

Figure 4. Boxplots for the 3 braced conditions and the unbraced condition showing maximal inversion within 100 ms after unexpected tilting of the left ankle on the platform.

between the hinged models Embrace and Ankle X ($Z = -3.05$, $P = .001$) such that the Ankle X brace demonstrated the greatest amount of restriction.

Passively Induced Foot Movements

All ankle braces restricted passively induced inversion and eversion angles compared with the unbraced condition ($P < .001$; Table). In the sagittal plane, dorsiflexion and plantar flexion were greater without a brace compared with all brace conditions ($P < .001$; Figure 6, Table). The hinged Embrace model demonstrated a greater plantar-flexion angle and allowed more motion than the hinged Ankle X ($Z = -2.87$, $P = .002$) and the nonhinged AirGo ($Z = -2.69$, $P = .007$). Furthermore, plantar flexion was greater in the hinged Ankle X than in the nonhinged AirGo ($Z = -3.53$, $P < .001$). In the transverse plane, internal rotation of the ankle was limited in all brace models compared with the unbraced condition ($P < .001$). During external rotation, the hinged models Ankle X and Embrace demonstrated a stabilization effect compared with the unbraced condition ($Z = -2.73$, $P = .004$; $Z = -3.21$, $P < .001$).

Correlation Between Dynamic and Passive Testing. We found low and nonsignificant correlations between measures of inversion on the tilting platform and passive inversion for the unbraced condition ($r = 0.32$, $P = .200$) and the hinged Embrace ($r = 0.23$, $P = .370$). For the hinged Ankle X and the nonhinged AirGo, the correlation was negative ($r = -0.23$, $P = .374$; $r = -0.22$, $P = .389$, respectively).

DISCUSSION

All 3 braces offered a significant stabilizing effect compared with the unbraced control condition. The total inversion angle on the tilting platform in the dynamic condition without wearing a brace (median = 41.8°) in this study was comparable with previous results.[10,17] The hinged Ankle X provided a more pronounced stabilizing effect during suddenly induced inversion on the tilting platform than the hinged Embrace and the nonhinged model. The hinged Ankle X reduced the dynamic inversion angle by 45%, the nonhinged brace by 36%, and the hinged Embrace model by 35%, results that were similar to the effects of semirigid braces in a previous study[10] involving restrictions ranging from 31% to 49%. The median angle of total inversion of the nonhinged brace (24.6°) was similar to the mean inversion with the nonhinged Aircast Air-Stirrup.[17] The inversion angles in the no-brace condition measured by Podzielny and Hennig[17] and Anderson et al[16] were lower (38° and 27°, respectively) and might be due to the smaller inversion angles of the tilting platform (26° and 22°, respectively). Furthermore, 3-dimensional analysis of rear-

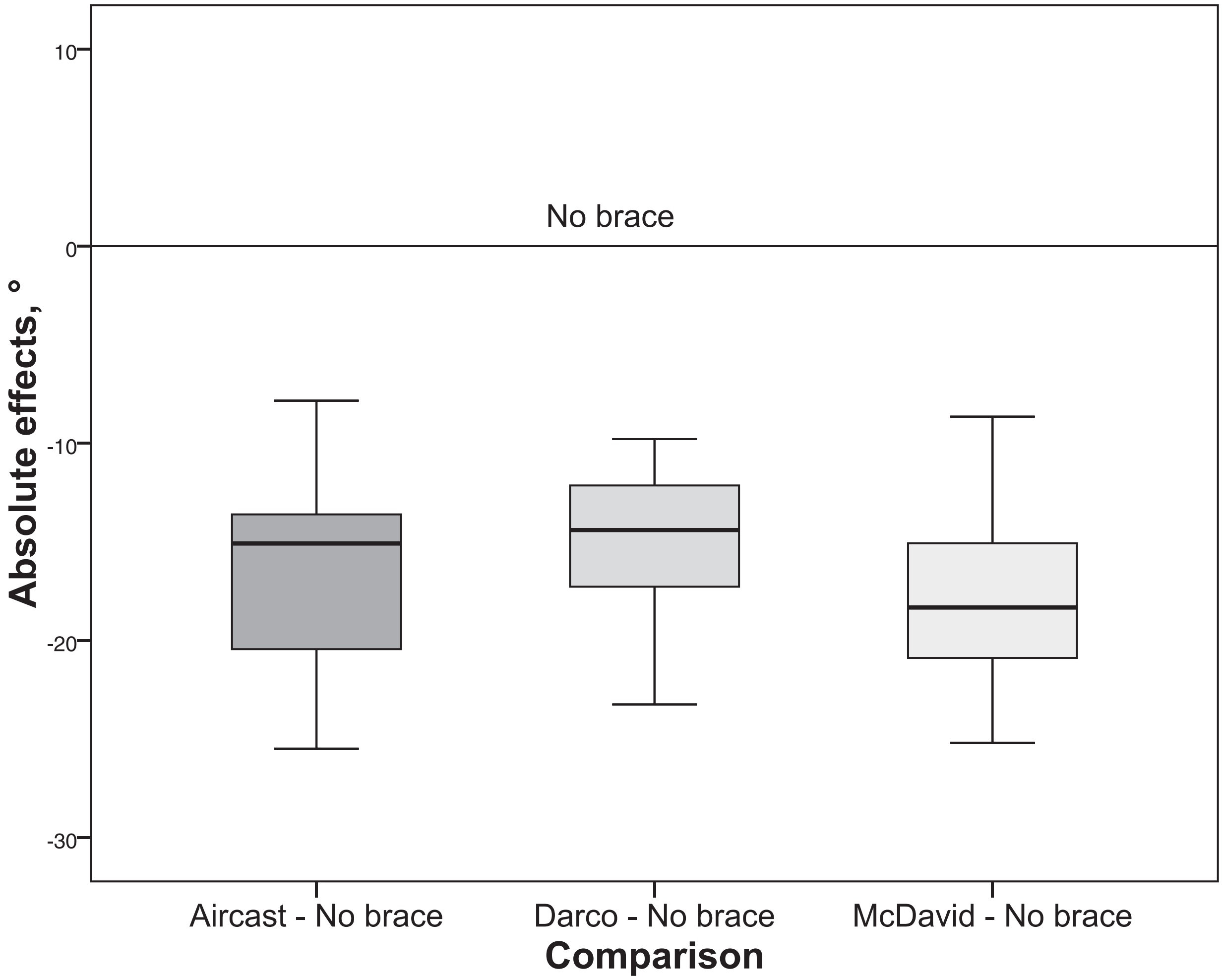


Figure 5. Absolute effects (mean of the individual differences of inversion angles [°]) during unexpected ankle tilting of the left ankle joint on the tilting platform. The zero line represents the median of the unbraced condition. The boxplots represent the braced conditions and show how much the braces constrained foot inversion compared with the unbraced condition.

foot motion during run-and-cut movements revealed inversion angles of 38°[26] and 45°[27] in trials that unfortunately resulted in ankle sprains. In comparisons between the sprain and the 2 control conditions measured by Kristianslund et al,[26] the trial with the sprain showed the smallest inversion sidestep-cutting angle (38° versus 39° and 41°). These findings may indicate that a critical hindfoot-inversion angle measured with an electromechanical in-shoe goniometer during sudden platform tilting and with 3-dimensional motion analysis during run-and-cut movements could not be predicted. However, investigations[26–29] of 3-dimensional motion analysis consistently showed higher peak angular velocities in trials of running, cutting, and jump landings when sprains occurred. We did not test angular velocities in the present study; however, Cordova et al[30] and Tang et al[31] demonstrated reduced angular excursion and velocity during inversion triggered by a tilting platform in participants wearing a semirigid ankle brace compared with those wearing a lace-up brace and control conditions.

Table. Dynamic and Passive Movement Angles (°) on the Tilting Platform and in the Custom-Built Fixture

				Brace								
	No Brace			Aircast AirGo			DARCO Body Armor Embrace			McDavid Ankle X		
Direction	Median	Minimum	Maximum	Median	Minimum	Maximum	Median	Minimum	Maximum	Median	Minimum	Maximum
Dynamic												
Inversion	41.8	32.2	47.3	24.6	19.0	30.8	27.1	18.2	32.3	23.6	14.6	30.7
Passive												
Inversion	53.3	32.7	59.0	31.7	22.0	54.3	27.0	21.7	52.3	31.0	20.3	53.3
Eversion	35.3	21.3	51.3	27.7	13.0	46.0	27.3	15.7	43.0	25.3	12.7	45.3
Dorsiflexion	21.3	7.7	33.7	17.7	5.3	30.3	18.7	6.0	30.3	18.7	6.0	32.3
Plantar flexion	45.0	34.3	57.3	27.7	22.3	36.0	40.7	33.7	54.0	37.3	28.3	50.3
Internal rotation	46.7	24.3	57.0	37.0	18.0	57.0	38.0	18.0	54.0	38.3	17.0	56.7
External rotation	44.3	25.3	57.0	44.7	21.0	57.0	37.0	17.0	57.0	37.3	21.7	57.0

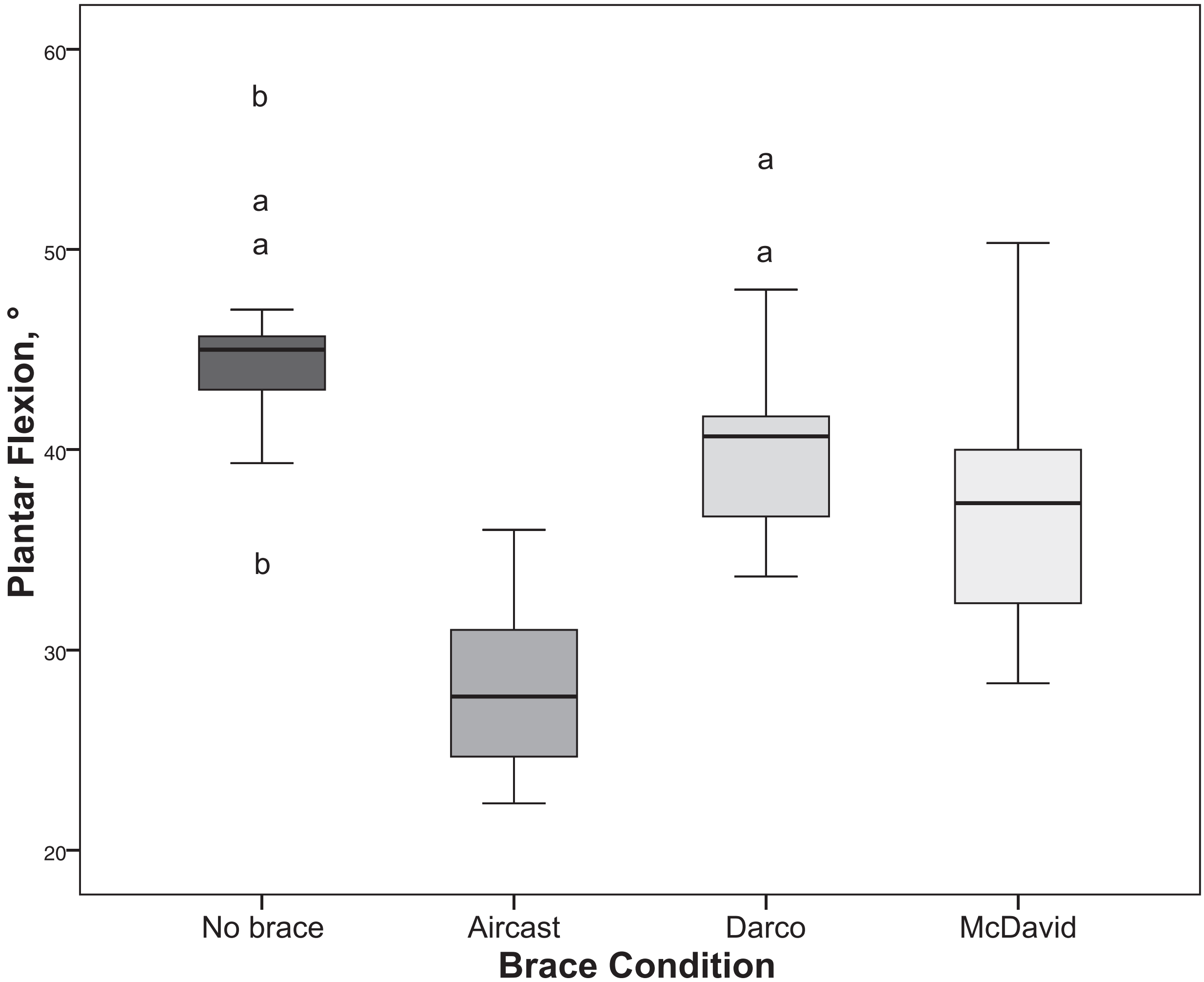


Figure 6. Boxplots showing the differences of passive plantar-flexion angles (°) of the left ankle joint at a torque of 9 Nm among the 4 brace conditions. No brace versus all brace conditions ($P < .001$); hinged DARCO Body Armor Embrace model versus nonhinged Aircast AirGo model ($P < .001$); hinged Body Armor Embrace model versus hinged McDavid Ankle X model ($P = .002$); nonhinged Aircast AirGo model versus hinged Ankle X model ($P < .001$). The nonhinged Aircast AirGo model restricted plantar flexion the most. [a] Moderate outlier. [b] Extreme outlier.

The more pronounced stabilization effect of the hinged Ankle X model and the nonhinged model might be due to their design, which encompasses the ankle more than the hinged Embrace model does; the latter has a narrower plastic stirrup at both sides of the ankle. This stirrup construction probably allows for greater mobility of the hindfoot in the brace. Therefore, a residual risk of an ankle sprain may remain. Furthermore, a more comprehensive enclosure of the ankle might have facilitated an improved peroneus longus reflex response. Lace-up and semirigid braces influence peroneus longus stretch reflex in both the short and long term by increasing reflex amplitude.[32] Improved sensorimotor function due to stimulation of cutaneous mechanoreceptors was proposed to explain this occurrence. However, the peroneus longus H/M_{max} ratio (the ratio of the maximum Hoffmann reflex to the maximum muscle response) was not altered in H-reflex measurements during a sudden dynamic-inversion perturbation on a tilting platform, leading to the assumption that mechanical stabilization afforded by ankle braces reduces the need for a peroneus longus reflex response.[20]

The different strapping systems of the braces might have led to differences in restricting maximal inversion angle. The straps of the hinged Embrace are narrower than the single strap of the nonhinged brace. The hinged Ankle X brace has a different design, with an extensive external cast and a wider strap encompassing the ankle joint.

In accordance with previous results,[10,11,19,33–35] we found that the braces restricted passive motion in all directions. Passive inversion in the no-brace condition in our study was greater (median = 53.3°) than in the studies of Eils et al[10,11] (means = 39° and 38°) and Siegler et al[19] (mean = 34°) because the applied torque was about 2 Nm greater. The same observations were made in the other directions. The plantar-flexion angle at a torque of 9 Nm in our study (median = 45°) was comparable with the angle of 47° at a torque of 9.7 Nm.[11] The hinged braces allowed greater passive plantar flexion than the nonhinged brace. Most ankle sprains occur during running, landing, or cutting.[36] However, the inversion and internal-rotation loads during a sidestep-cutting maneuver exceeded the injury threshold shortly after initial foot contact when the foot was dorsiflexed.[26] Furthermore, the foot is usually accelerated into dorsiflexion during jump landings,[36] so external stabilization against plantar flexion could go undetected.

Range of motion during rotational movements was greater than reported in references.[10,11,34] This might be due in part to the problem of fixing the leg against rotation, which is difficult with the soft tissue of the lower leg. However, the mean torques of internal rotation ranged only from 4.9 to 6.7 Nm. For external rotation, they were only 6.1 Nm.[10,11] During passive external rotation, the non-hinged brace showed less stabilization at a torque of 9 Nm than the other models. The shell of this brace model seems to be pliable compared with the hinged braces, which have shells and stirrups made of more rigid plastic material. Rotation was less restricted by all braces, so the braces cannot be recommended to avoid rotational movements to the limits of comfort.

Based on our results, we suggest the following: Because it showed a greater limitation of passive plantar flexion and more mechanical stabilization than the hinged Embrace model, the nonhinged brace is recommended when the ankle needs more external-stabilization support. Because it demonstrated the most effective stabilization compared with the other tested braces, the hinged Ankle X model is recommended when the ankle needs more external support. Because it offered the least restricted mobility in the sagittal plane during plantar flexion but stabilized the ankle sufficiently during inversion, the hinged Embrace model could be useful to protect healthy ankles during sport activities. We did not explore the effects of the braces on tissue healing, so we cannot make any recommendations in this area, which must be clarified in further investigations.

It is interesting to note that we found no correlation between inversion on the tilting platform and passive inversion, as reported by Eils et al,[10] indicating that passive testing was not comparable with dynamic testing. Our findings show that a brace recommendation should not be based on only 1 testing procedure given that dynamic and passive range of inversion are not interchangeable as previously proposed.[24] A possible reason for the differences between dynamic and passive testing is that neuromuscular activation, depending on the speed of foot inversion, may have had an important influence in the dynamic condition. Latency time of the peroneus muscle, total inversion time, maximum inversion speed, and mean and maximal angular inversion speeds are key time variables in dynamic foot inversion[37] and do not exist in passive inversion.

Limitations

A limitation might be that we studied only healthy participants and no patients with injured or chronically unstable ankles. To compare functional stabilization among different types of braces, biomechanical investigations are considered more useful than clinical studies.[17] Accordingly, the procedures in this study appear to be appropriate. A further limitation might have been that no additional plantar-flexion movement of the foot of about 15° during ankle tilting was induced on the tilting platform, as demonstrated in literature.[38–39] For comprehensive results, all degrees of freedom of the ankle were tested passively as well. However, sport-related movements such as running, jumping, or cutting maneuvers (during which most ankle injuries occur), and the stabilizing effects of braces during ankle sprain mechanisms deserve further biomechanical investigation.[9,26,29,40]

CONCLUSIONS

The results of our study demonstrated that all 3 tested braces provided substantial stabilizing effects against dynamic foot inversion. The hinged braces did not offer less stabilization against inversion and internal and external rotation during passive range of motion testing or against rapidly induced inversion on the tilting platform. Therefore, the braces appear to be effective when external stabilization of the ankle joint is required.

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