Influence of External Ankle Support on Lower Extremity Joint Mechanics During Drop Landings

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Objective: To investigate the effects of external ankle support (EAS) on lower extremity joint mechanics and vertical ground-reaction forces (VGRF) during drop landings. Design: A $1 \times 3$ repeated-measures, crossover design. Setting: Biomechanics research laboratory. Patients: 13 male recreationally active basketball players (age $22.3 \pm 2.2$ y, height $177.5 \pm 7.5$ cm, mass $72.2 \pm 11.4$ kg) free from lower extremity pathology for the 12 mo before the study. Interventions: Subjects performed a 1-legged drop landing from a standardized height under 3 different ankle-support conditions. Main Outcome Measures: Hip, knee, and ankle angular displacement along with specific temporal (TGRFz1, TGRFz2; s) and spatial (GRFz1, GRFz2; body-weight units [BW]) characteristics of the VGRF vector were measured during a drop landing. Results: The tape condition ($1.08 \pm 0.09$ BW) demonstrated less GRFz1 than the control ($1.28 \pm 0.16$ BW) and semirigid conditions ($1.28 \pm 0.21$ BW; $P < .0001$), and GRFz2 was unaffected. For TGRFz1, no-support displayed slower time ($0.017 \pm 0.004$ s) than the semirigid ($0.014 \pm 0.001$ s) and tape conditions ($0.014 \pm 0.002$ s; $P < .05$). For TGRFz2, no-support displayed slower time ($0.054 \pm 0.006$ s) than the semirigid ($0.050 \pm 0.006$ s) and tape conditions ($0.045 \pm 0.004$ s; $P < .05$). Semirigid bracing was slower than the tape condition, as well ($P < .05$). Ankle-joint displacement was less in the tape ($34.6^\circ \pm 7.7^\circ$) and semirigid ($36.8^\circ \pm 9.3^\circ$) conditions than in no-support ($45.7^\circ \pm 7.3^\circ$; $P < .05$). Knee-joint displacement was larger in the no-support ($45.1^\circ \pm 9.0^\circ$) than in the semirigid ($42.6^\circ \pm 6.8^\circ$; $P < .05$) condition. Tape support ($43.8^\circ \pm 8.7^\circ$) did not differ from the semirigid condition ($P > .05$). Hip angular displacement was not affected by EAS ($F_{2,24} = 1.47$, $P = .25$). Conclusions: EAS reduces ankle- and knee-joint displacement, which appear to influence the spatial and temporal characteristics of GRFz during drop landings.

Keywords: bracing, joint kinematics, ground-reaction forces
Athletic activity causes a high risk of injury to the foot and ankle joints. Nearly 85% of ankle injuries are caused by extreme inversion combined with plantar flexion and involve the lateral ligamentous structures of the ankle joint. In addition, lateral ankle injuries can disrupt the peroneal muscles, superficial peroneal nerve, and ankle-joint mechanoreceptors. The use of various types of external ankle support is extremely effective in reducing the risk of ankle injuries.

The main goal of prophylactic ankle support is to restrict excessive inversion of the ankle–foot complex while allowing normal ankle dorsiflexion and plantar flexion to maintain performance. A comprehensive statistical analysis of the literature demonstrated that both ankle taping and bracing restricted not only inversion and eversion in the subtalar joint but also plantar flexion and dorsiflexion in the talocrural joint. Specifically, it has been shown that before exercise, semirigid ankle braces significantly restricted inversion range of motion (ROM) 21.3% more than tape and 26.2% more than lace-up-style ankle braces. In addition, semirigid ankle braces restricted inversion ROM 72.1% more than tape and 59.5% more than lace-up ankle braces. Dorsiflexion ROM was restricted 38.3% more with tape than with a lace-up ankle brace, whereas there was no significant difference between tape (9.1°) and lace-up-style ankle braces (9.7°) in overall plantar-flexion ROM restriction.

Landing from a jump is a common task in many sports that serves as the primary mechanism of many lower extremity injuries. This is especially the case in basketball and volleyball, in which athletes tend to use external ankle support prophylactically. It is no surprise that ankle function during drop landings under various external-ankle-support conditions has been the object of frequent study. For instance, 3 studies have demonstrated the importance of eccentrically controlling ankle plantar flexion and dorsiflexion for energy absorption with ankle taping and bracing during landing. Reduced ankle plantar flexion and dorsiflexion during drop landings with ankle taping appear to result in less energy absorbed by the tissues controlling ankle motion, especially by eccentric action of the posterior ankle musculature, resulting in greater peak vertical ground reaction forces (VGRF) at heel contact. In addition, soleus-muscle activity was less from impact to vertical ground reaction under the taped condition than the no-support condition. Riemann et al also demonstrated that the time to reach peak VGRF (GRFz) was significantly less and the peak vertical impact forces were greater during drop landings with the ankle braces and tape conditions. This was found before and after treadmill jogging in comparison with the control (no-support) condition. Furthermore, tape and a tape-spat combination exhibited a significantly higher impact force and a shorter temporal interval to attain the peak impact force than a control condition during drop landings. Significant alterations in anteroposterior ankle-joint kinematics with ankle taping and bracing have been documented. Specifically, decreased plantar flexion at ground contact and reduced dorsiflexion during the impact phase of ground contact have been found.

These alterations led to the hypothesis that ankle taping and bracing may influence impact absorption during drop landings, which may lead to an increase in energy absorption at the knee and hip joints. The knee and hip joints also participate in energy absorption during landing, yet previous investigations in this area have not assessed alterations in knee- and hip-joint ROM under various ankle-support conditions. It is not known whether the application of tape or...
a semirigid ankle brace at the ankle influences knee- and hip-joint kinematics during a 1-legged drop landing and whether potential kinematic changes to the joints proximal to the ankle manifest into alterations in VGRF during the landing. Understanding lower extremity joint kinematics and VGRF will provide insight into whether external ankle supports are effective in reducing lower extremity joint loading during a functional task. Therefore, the purpose of this investigation was to evaluate whether external ankle support affects the selected temporal and spatial characteristics of the VGRF vector and hip, knee, and ankle angular displacement in the sagittal plane during a 1-legged drop landing.

**Methods**

A $1 \times 3$ repeated-measures design was used to guide this study. The single independent variable was external ankle support with 3 conditions: basket-weave tape application, semirigid ankle brace, and no support. A series of VGRF variables and lower extremity joint kinematic variables served as the dependent measures. The VGRF variables (Figure 1) included first peak vertical impact force (GRFz1), second peak vertical impact force (GRFz2), time to first peak vertical impact force (TGRFz1), and time to second peak vertical impact force (TGRFz2). The lower extremity joint kinematic variables included sagittal-plane angular displacement of the hip, knee, and ankle from initial contact of the toe on the force platform to the maximum joint angle that occurred for each joint during the landing.

![Figure 1](image_url)

**Figure 1** — Representative vertical-ground-reaction-force curve from a drop landing. The 4 variables considered are labeled as follows: first peak impact force GRFz1, second peak impact force GRFz2, time to first peak impact force TGRFz1, and time to second peak impact force TGRFz2.
Subjects

Thirteen healthy male college students (age 22 ± 2 y, height 177 ± 7 cm, mass 72 ± 11 kg, maximum vertical jump height 37 ± 4 cm) volunteered for the study. All subjects participated in recreational basketball at least 2 or more days per week, which ensured that they were used to landing from a jump. Subjects were excluded from the study if they reported any lower extremity injuries or neurological disorders during the 12 months before enrolling in the study that would adversely affect their ability to jump or land from a jump. Moreover, it was required that each subject be able to perform a single-leg vertical jump higher than 30.5 cm so that the body’s deceleration could be controlled after landing. All subjects provided written informed consent before participating, and the study was approved by the university’s institutional review board.

Instruments

**Force Platform.** A piezoelectric force platform (model # 9861A, Kistler, Winterthur, Switzerland) recessed in the floor was used to collect the VGRF data. The VGRF data were amplified (1000 N/coulomb) and digitally converted at 1000 Hz for a total duration of 1.0 second. A pretrigger rate data-collection buffer representing 20% of the total time period was used, and the trigger load for the vertical force was established at 10.0 N. The raw data were low-passed filtered using a second-order, zero-lag Butterworth digital filter with the frequency cutoff set at 10 Hz. The processed data were then analyzed by using the Ariel APAS analog module (Ariel Dynamics, Inc, San Diego, CA) to quantify the specific temporal and spatial VGRF variables. The processed VGRF data were normalized to each subject’s body weight (BW); thus, a 1.5-BW unit of force suggests that a 150-lb (68-kg) subject produced 225 lb (102 kg) of force during the landing. The temporal variables were measured in seconds.

**Videography.** A sagittal-plane-view recording of each drop-landing trial was captured for all of the ankle-support conditions at 60 Hz with a digital video camera (Mini DV 9800, JVC, Japan). The camera was set at a height of 1.1 m and positioned 5.0 m from the landing area in the sagittal plane. This provided a lateral field of view 2.8 m wide and 2.3 m high. The capture space was calibrated using the data points and control points from a standard calibration cube. The joint-center coordinate data from each marker were digitized and transformed using a 2-dimensional direct-linear-transformation algorithm with the Ariel APAS software. The transformed data files were then filtered using a second-order Butterworth low-pass digital filter with the cutoff frequency set at 6 Hz. The processed x- and y-coordinate data representing each marker were then used to calculate the angular displacement of the hip, knee, and ankle joints in the sagittal plane during contact with the force platform. The Ariel APAS system has been demonstrated to yield reliable and valid spatial-coordinate and angular-positional data using video cameras.25

Testing Procedures

Each subject was asked to report to the biomechanics laboratory on 2 consecutive days separated by 24 hours. On the first day subjects went through a screening and orientation session, and the second day served exclusively for data collection.
Screening and Orientation Day. On the first day, subjects provided informed consent and completed a health-history questionnaire to establish whether they met the inclusion criteria. They were then informed about the testing procedures of the experiment. Subjects performed a maximum single-leg vertical jump with the dominant jumping leg to establish whether they could jump the same height that they would be landing from. The dominant jumping leg was defined as the leg with which subjects were able to achieve the greatest height above 30.5 cm during a 1-legged vertical jump. Subjects who were able to jump above 30.5 cm were selected to participate in the study. After it was determined that subjects met the qualifications for the study, they were instructed in the landing technique for the study. The technique employed in this study was similar to what has been previously reported in the literature. Specifically, the landing technique was controlled by having the subjects place their hands on their iliac crests while standing on their contralateral leg with half of their foot hanging off of a box that was 30.5 cm high. They were then instructed to relax the foot of the dominant leg while resting the bottom of the foot of the test leg at the same level as the platform. The subjects practiced the landing technique for each of the 3 ankle-support conditions until the evaluators determined that they were consistently landing with the correct technique.

Testing Day. Before collecting the data, we placed 1.5-cm-diameter reflective spherical markers on the following anatomical landmarks nearest the camera: lateral shoe upper at the head of the fifth metatarsal, lateral malleolus of the fibula, center of the lateral knee-joint line, center of the lateral hip joint, center of the lateral shoulder joint, lateral epicondyle of the humerus, wrist joint, chin, and forehead. To track the movement of the nondominant extremity, markers were placed on the following landmarks: medial head of the first metatarsal, medial malleolus of the tibia, and the center of the medial knee-joint line. Specific joint kinematics of the nondominant extremity were not analyzed in this study.

Before data collection during the second session, subjects were given practice time to refamiliarize themselves with the landing technique. After this, they performed 5 landing trials under each of the 3 ankle-support conditions using a balanced Latin-square design: control (no ankle support), semirigid ankle brace (Ultra ankle brace, McDavid, Inc, Woodridge, IL), and ankle taping (Zonas, Johnson & Johnson Sports Medicine). The ankle brace was applied in accordance with the manufacturer’s recommendations, and the ankle taping was applied in a traditional closed basket-weave configuration. All the external-ankle-support conditions were applied by the same certified athletic trainer to all subjects to ensure consistency in the application, and subjects were instructed to wear low-cut cross-training shoes.

Each landing trial for all conditions was video-recorded and synchronized to the force-platform data acquisition. Each subject performed the drop landings on the force platform until 5 successful trials were completed under each testing condition. If a subject lost his balance while landing or removed his hands from his hips during the landing, the trial was determined to be unsuccessful and was redone. All subjects received a 5-minute break after each condition was completed, in which they remained seated and prepared for the next set of trials under a different ankle-support condition. After the trials were completed, the VGRF variables and joint kinematic variables were extracted from the computer and prepared for statistical analysis.
Statistical Analysis

Two $1 \times 3$ repeated-measures MANOVAs were performed. The first model was used to assess the effects of external ankle support on the linear combination VGRF variables. Follow-up univariate $F$ tests were then used to assess the effects of external ankle support on each VGRF variable separately. The second $1 \times 3$ repeated-measures MANOVA was used to assess the effects of ankle support on the linear combination of knee, hip, and ankle angular joint displacement. After a significant MANOVA, separate ANOVAs were performed evaluating the effects of external ankle support on each joint kinematic variable separately. A Sidak $t$ multiple-comparison procedure was used post hoc to locate specific group differences. The level of significance was established at $P < .05$ for all tests.

Results

The means, standard deviations, and 95% confidence intervals for the VGRF variables and joint angular displacement measures by external-ankle-support condition are shown in Tables 1 and 2. There was an overall multivariate effect of external ankle support on the linear combination of GRFz1, GRFz2, TGRFz1, and TGRFz2 (Wilks $\Lambda = 0.163, F_{8,44} = 7.76, P < .0001$). When considered univariately, external ankle support did affect GRFz1 ($F_{2,24} = 16.89, P < .001$), TGRFz1 ($F_{2,24} = 11.46, P < .001$), and TGRFz2 ($F_{2,24} = 16.7, P < .001$). Post hoc analysis revealed that the control and semirigid-ankle-brace conditions demonstrated greater GRFz1 than the tape condition ($P < .05$); however, the control (no-support) condition was not different from the semirigid condition ($P > .05$). For the variable GRFz2, no effect of the ankle-brace condition was observed ($F_{2,24} = 2.61, P = .09$). When assessing the effects of ankle-brace condition on the temporal VGRF variables, the control condition revealed a slower time than both the tape and semirigid support conditions for TGRFz1 and TGRFz2 ($P < .05$). In addition, for TGRFz1 the tape and semirigid conditions did not differ from each other ($P > .05$), whereas the tape condition exhibited a faster TGRFz2 than the semirigid-brace condition ($P < .05$).

Table 1  Vertical-Ground-Reaction-Force Variables by Ankle-Support Condition, Mean ± SD (95% CI)

<table>
<thead>
<tr>
<th>Condition</th>
<th>GRFz1 (BW)</th>
<th>GRFz2 (BW)</th>
<th>TGRFz1 (s)</th>
<th>TGRFz2 (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No support</td>
<td>1.28 ± 0.16</td>
<td>4.50 ± 0.61</td>
<td>0.017 ± 0.004#</td>
<td>0.054 ± 0.006</td>
</tr>
<tr>
<td></td>
<td>(1.18–1.38)</td>
<td>(4.13–4.86)</td>
<td>(0.015–0.019)</td>
<td>(0.015–0.019)</td>
</tr>
<tr>
<td>Tape</td>
<td>1.08 ± 0.09*</td>
<td>4.67 ± 0.74</td>
<td>0.014 ± 0.002</td>
<td>0.045 ± 0.004§</td>
</tr>
<tr>
<td></td>
<td>(1.02–1.13)</td>
<td>(4.22–5.12)</td>
<td>(0.013–0.015)</td>
<td>(0.043–0.048)</td>
</tr>
<tr>
<td>Semirigid</td>
<td>1.28 ± 0.21</td>
<td>4.51 ± 0.58</td>
<td>0.014 ± 0.001</td>
<td>0.050 ± 0.006</td>
</tr>
<tr>
<td></td>
<td>(1.15–1.41)</td>
<td>(4.17–4.86)</td>
<td>(0.013–0.015)</td>
<td>(0.046–0.053)</td>
</tr>
</tbody>
</table>

Abbreviations: GRFz1, first peak impact force; BW, body-weight unit; GRFz2, second peak impact force; TGRFz1, time to first peak impact force; TGRFz2, time to second peak impact force.

*Significantly less than the no-support and semirigid-ankle-brace conditions ($P < .05$). #Significantly slower than the tape and semirigid-ankle-brace conditions ($P < .05$). §Significantly faster than the control and semirigid-ankle-brace conditions ($P < .05$).
In examining the effects of external ankle support on the linear combination of ankle, knee, and hip angular displacements, an overall multivariate effect was observed ($F_{6,46} = 6.09, P < .001$). When considered univariately, external ankle support affected ankle-joint displacement ($F_{2,24} = 23.40, P < .001$; Figure 2) and knee-joint displacement ($F_{2,24} = 3.58, P = .043$; Figure 2). External ankle support did not affect hip-joint displacement ($F_{2,24} = 1.47, P = .25$; Figure 2). For ankle-joint displacement, subsequent post hoc testing revealed that the control condition exhibited greater displacement than the tape and semirigid-ankle-brace conditions ($P < .05$). Furthermore, the tape and semirigid-ankle-brace conditions did not differ from each other ($P > .05$). For knee-joint displacement, post hoc analysis showed that the control condition caused greater displacement than the semirigid-ankle-brace condition ($P < .05$).

### Table 2 Ankle, Knee, and Hip Angular Displacement (°) by Ankle-Support Condition, Mean ± SD (95% CI)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Ankle ROM</th>
<th>Knee ROM</th>
<th>Hip ROM</th>
</tr>
</thead>
<tbody>
<tr>
<td>No support</td>
<td>45.7 ± 7.3*</td>
<td>45.1 ± 9.0§</td>
<td>20.1 ± 6.0</td>
</tr>
<tr>
<td></td>
<td>(41.3–50.1)</td>
<td>(39.7–50.6)</td>
<td>(17.3–24.6)</td>
</tr>
<tr>
<td>Tape</td>
<td>34.6 ± 7.7</td>
<td>43.8 ± 8.7</td>
<td>23.0 ± 8.6</td>
</tr>
<tr>
<td></td>
<td>(29.9–39.2)</td>
<td>(38.6–49.1)</td>
<td>(17.8–28.2)</td>
</tr>
<tr>
<td>Semirigid</td>
<td>36.8 ± 9.3</td>
<td>42.6 ± 6.8</td>
<td>21.9 ± 5.6</td>
</tr>
<tr>
<td></td>
<td>(31.2–42.5)</td>
<td>(38.5–46.7)</td>
<td>(18.5–25.3)</td>
</tr>
</tbody>
</table>

Abbreviations: ROM, range of motion.
*Significantly greater than the tape and semirigid-ankle-brace conditions ($P < .05$). §Significantly greater than the semirigid-ankle-brace condition ($P < .05$).

![Figure 2](image-url) — Angular joint displacement by external-ankle-support condition. *$P < .05$. 
Discussion

In the current study, we sought to investigate the potential effects that common forms of external ankle support may have on various temporospatial components of the VGRF vector after a single-leg drop landing. In addition, we were also interested in investigating whether changes in vertical impact forces would manifest into joint kinematic differences at the ankle, knee, and hip under the same ankle-support conditions. We hypothesized that extensive loading at the ankle–foot complex would cause compensatory kinematic changes at the knee and hip to allow the forces on the lower extremity kinetic chain to be dissipated. Because certified athletic trainers commonly employ external ankle support to prevent acute and chronic ankle injury, it is essential to study the lower extremity kinematic and kinetic characteristics during a functional athletic task.

Temporal VGRF

Because the GRFz1 represents the greatest amount of force attenuated by the metatarsal heads during initial foot contact,16 we hypothesized that the tape condition would cause a larger GRFz1 than the other 2 ankle-support conditions because of restricted sagittal-plane ROM and inherent stiffness created by the basket-weave tape application. Because the no-support and semirigid-ankle-support conditions allow for greater sagittal-plane motion than the tape condition, we surmised that the diminished ROM would manifest into a larger initial peak vertical impact force; however, our data demonstrated the exact opposite. Specifically, the no-support (control) and semirigid-ankle-brace conditions caused nearly 0.2 BW units more force at initial impact (GRFz1) than the tape condition. Although the tape application does act to stiffen the ankle–foot complex by reducing the amount of plantar-flexion ROM at initial contact, it appears that the amount of stiffness applied represented an ideal compromise between mechanical restriction and mobility. This is precisely the level of compromise sports-medicine practitioners anticipate with the application of external ankle support. Another plausible mechanism for the tape condition’s demonstrating less GRFz1 may be attributed to the adhesive tape, on initial contact, acting to redistribute the initial peak vertical loading to structures farther along in the sagittal plane (ie, medial longitudinal arch), as well as redistributing the forces along the frontal plane. This load redistribution appears likely to be caused by the ability of the tape to conform more securely to the ankle–foot complex, as well as the structural tensile strength offered by the tape when applied in a basket-weave pattern. During metatarsal-head contact in the tape condition, the longitudinal arch may be assisted by the adhesive tape; thus, the loading may have been more directed along the anteroposterior and mediolateral axes of the foot instead of in the vertical direction.

The TGRFz1 represents the amount of time from initial toe contact to metatarsal-head contact; it is an important factor during a drop landing because it characterizes the time for energy absorption in the forefoot.16 The results of TGRFz1 demonstrated means of 0.017, 0.014, and 0.014 second in the no-support, tape, and semirigid-brace conditions, respectively. The no-support condition exhibited a 0.003-second longer time to reach GRFz1 than the tape and semirigid-ankle-brace conditions, which suggests that the ankle–foot complex was less rigid because of the faster rate at which the peak force was generated (eg, steeper slope in the
force–time curve). Furthermore, the longer time duration to reach GRFz1 observed in the no-support condition can also be the result of the distance needed for the metatarsal heads in be in full contact with the force platform. These 2 theories are supported by the fact that ankle plantar flexion tends to be more restricted with the tape and the semirigid brace. Our results are consistent with those of Yi et al, who demonstrated that peak VGRFs at toe contact were significantly greater for taped trials than with a no-support condition during drop landings.

The second set of temporospatial ground-reaction-force variables were GRFz2 and TGRFz2. Specifically, these variables are important in that they represent the maximum vertical force and time to maximum vertical force obtained during the drop landing, whereby most of the vertical impact force is absorbed during heel contact. With much larger vertical impact forces inherently placed on the leg during landing on a single leg from a height, we were hoping to magnify the effects of the treatments. We surmised that the tape and semirigid-ankle-brace conditions would result in a larger GRFz2 than the control condition based on previous work of Yi et al, who observed larger GRFz2 values with the tape condition than with the control condition. They suggested that reduced eccentric activity of the soleus muscle with the application of adhesive tape caused more vertical force (5.50 BW) than that produced during the no-support condition (5.03 BW). Although in our investigation we did not see any significant differences between the 3 ankle-support conditions, a similar trend in our GRFz2 data did demonstrate larger magnitudes of force during the tape condition (4.67 BW) than in the semirigid-ankle-brace (4.51 BW) and control (4.50 BW) conditions. When we evaluated these results by assessing the standardized effect size (Cohen $d$), the tape condition demonstrated a –0.27 standardized mean change compared with the control group, which is considered a small but substantial effect, whereas the semirigid ankle brace demonstrated virtually no effect (ES = .02). Our results, combined with previous findings, strongly suggest that most of the load may already have been attenuated by the forefoot and midfoot regardless of the ankle-support condition, whereby most of the impact loading that occurred during the entire drop landing was dissipated at immediate contact. Even though the magnitudes of force are higher at GRFz2, the impact forces at forefoot contact are mostly dissipated.

The shorter time to reach GRFz2 observed in both ankle-support conditions in the current investigation (tape 0.045 s, semirigid brace 0.050 s) helps confirm the approximation and consistency of the heel during the initial contact as previously discussed. Moreover, based on previous investigations, the eccentric activity of posterior lower leg muscles may be reduced with the tape and the semirigid ankle brace; decreased activation of the gastrocnemius and soleus muscles may further suggest that the posterior leg muscles, with some level of external ankle support, do not help decelerate the inertia of the body during drop landings. Although the magnitude of GRFz2 was not significantly different between the ankle-support conditions, the decreased time needed to reach GRFz2 indicates that the rate at which peak force is produced is increased. This has major implications in terms of how the stress is applied to the lower extremity kinetic chain, as well as how the stress is ultimately dissipated proximally along the kinetic chain. Even though the overall change observed in the GRFzs and TGRFzs may be viewed as insignificant, the potential for higher risk of foot and lower leg stress, pain, or injuries should not be ignored.
Lower Extremity Joint Angular Displacement

In addition to studying the influence of external ankle support on various temporo-spatial VGRF variables, this investigation also focused on the influence of external ankle support on lower extremity sagittal-plane joint kinematics. Although not measured in the current study, frontal- and transverse-plane motion of the hip, knee, and ankle could have also been influenced by external ankle support during the drop landing; however, because previous studies have shown a restriction of sagittal-plane ROM at the ankle with prophylactic ankle taping but not with a semirigid ankle brace, we hypothesized that only the tape condition would increase knee and hip ROM during drop landings to compensate for the expected ROM reduction at the ankle joint. Because of the mechanical restrictions provided by external ankle support, we believed that alterations in sagittal-plane knee- and hip-joint mechanics would occur to help dissipate the increased forces experienced at the ankle–foot complex because of the ankle support applied. The specific implications of external ankle support on the ankle, knee, and hip sagittal-plane kinematics follow.

Ankle ROM. For ankle-joint displacement, both the tape and semirigid-ankle-brace conditions showed significantly less ankle-joint ROM than the no-support condition, whereas no differences were observed between the tape and semirigid-brace conditions. The difference between the tape and no-support conditions was 11.1°, and the semirigid condition revealed 8.9° less angular displacement than the no-support condition. The outcome observed with the tape condition was expected because of the figure-8 and heel locks used in the basket-weave taping technique, which are intended to restrict ankle plantar flexion and dorsiflexion. As previously mentioned, the result found in the semirigid-ankle-brace condition was in direct contrast to what we hypothesized would occur. We deduced that the semirigid ankle brace would not restrict sagittal-plane ankle ROM based on the findings from 2 studies. Cordova et al demonstrated in their meta-analysis that under a preexercise condition, a total average of 17.1° of ankle ROM restriction was found with ankle taping, whereas application of semirigid ankle braces demonstrated an average restriction of 4.2°. Furthermore, McCaw and Cerullo found that a tape condition revealed significantly less ankle-joint ROM (32.9°) during 2-leg drop landings than the semirigid-ankle-brace condition (38.0°) and the no-support condition (39.4°). They found that the semirigid-ankle-brace condition did not significantly differ from the no-support condition. Our study revealed that not only does ankle tape significantly restrict ankle-joint ROM, but so does a semirigid ankle brace, when performing 1-legged drop landings.

Knee ROM. We hypothesized that knee-joint displacement would increase with the adhesive-tape and semirigid-ankle-brace conditions to absorb more energy for the compensation of kinematic and kinetic changes at the foot and ankle. However, the semirigid-ankle-brace condition demonstrated the least amount of knee-joint displacement (42.6°), followed by the tape condition (43.8°), and the no-support condition exhibited the greatest amount (45.1°). We believe that these results may have occurred because of limited freedom of the tibia rolling anteriorly on the talus with the tape and the semirigid-ankle-brace conditions. The mechanical restriction offered by these devices effectively caused the leg to become more confined to an upright position after heel contact, which may have resulted in the
body’s center of mass becoming more perpendicular to the ground. As a result, the knee joint did not have to produce as much flexion (controlled net extensor joint moment) with the ankle-support conditions to maintain stability of the center of mass. However, this position could be more indicative of a stiff landing that is often observed in gymnasts, in which greater reliance may be placed on knee-joint articular structures (eg, menisci and articular cartilage) to absorb the compressive loads imparted on the knee joint rather than being absorbed by the hip joint; thus, the impact loads are absorbed more by the passive structures of the joint, rather than eccentric loading of the quadriceps muscle group as the knee produces a flexion moment. The negative implication of this result is that it can lead to more stresses placed directly at the patellofemoral and tibiofemoral articulations.

Hip ROM. For hip-joint displacement, no significant differences ($P = .25$) were observed between the 3 external-ankle-support conditions. These findings may be attributed to the fact that the force placed on the lower extremity could already have been attenuated by the musculature controlling the ankle and knee joints, as well as direct attenuation experienced directly at the articular surfaces, independent of the external ankle support applied. It is interesting to note that regardless of external ankle support applied, the hip joint underwent the least amount of total angular displacement compared with the knee and ankle joints. Our data are supported by Schmitz et al., who studied single-leg drop landings from a similar (0.3-m) height. In their investigation, they found that the hip joint exhibited less total flexion during landing than the knee and ankle joints when collapsed across sex. Furthermore, DeVita and Skelly showed that the contribution of energy absorption in the hip was significantly less than that of the knee and ankle joints during soft landings (25% compared with 37%); therefore, it is conceivable that the hip-joint range of motion observed in the current study remained unchanged under the ankle-support conditions, unlike what was observed at the ankle and knee joints, because of the relatively low contribution of the hip joint to the total lower extremity force absorption during a drop landing.

Clinical Relevance and Summary

Landing from a jump is a common occurrence that results in a relatively high risk of lateral ankle injury during athletic activities because of the vulnerable position of ankle plantar flexion with an applied inversion load to the foot. External ankle support has been shown to effectively reduce ROM of the ankle–foot complex, prevent the incidence of acute ankle injuries, protect injured ankles from further injuries, and not affect various lower extremity functional tests. In the current study, we limited our investigation to studying lower extremity sagittal-plane joint kinematics and characteristics of the VGRF vector with external ankle support during drop landings. Consistent with previous investigations, ankle taping and semirigid ankle bracing demonstrated higher rates of force applied to the body. This may suggest that rapid impact loading induces greater stress to the leg because of the ankle supports’ restricting ankle and knee sagittal-plane ROM. The significant decrease in sagittal-plane ankle- and knee-joint ROM caused by external ankle support may indicate that subjects employed a more upright landing strategy to compensate for the constraint and decreased degrees of freedom imposed by the external ankle support.
References


