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Ankle-Dorsiflexion Range of Motion and Landing Biomechanics

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Context: A smaller amount of ankle-dorsiflexion displacement during landing is associated with less knee-flexion displacement and greater ground reaction forces, and greater ground reaction forces are associated with greater knee-valgus displacement. Additionally, restricted dorsiflexion range of motion (ROM) is associated with greater knee-valgus displacement during landing and squatting tasks. Because large ground reaction forces and valgus displacement and limited knee-flexion displacement during landing are anterior cruciate ligament (ACL) injury risk factors, dorsiflexion ROM restrictions may be associated with a greater risk of ACL injury. However, it is unclear whether clinical measures of dorsiflexion ROM are associated with landing biomechanics.

Objective: To evaluate relationships between dorsiflexion ROM and landing biomechanics.

Design: Descriptive laboratory study.

Setting: Research laboratory.

Patients or Other Participants: Thirty-five healthy, physically active volunteers.

Intervention(s): Passive dorsiflexion ROM was assessed under extended-knee and flexed-knee conditions. Landing biomechanics were assessed via an optical motion-capture system interfaced with a force plate.

Main Outcome Measure(s): Dorsiflexion ROM was measured in degrees using goniometry. Knee-flexion and knee-valgus displacements and vertical and posterior ground reaction forces were calculated during the landing task. Simple correlations were used to evaluate relationships between dorsiflexion ROM and each biomechanical variable.

Results: Significant correlations were noted between extended-knee dorsiflexion ROM and knee-flexion displacement ($r = 0.464$, $P = .029$) and vertical ($r = -0.411$, $P = .014$) and posterior ($r = -0.412$, $P = .014$) ground reaction forces. All correlations for flexed-knee dorsiflexion ROM and knee-valgus displacement were nonsignificant.

Conclusions: Greater dorsiflexion ROM was associated with greater knee-flexion displacement and smaller ground reaction forces during landing, thus inducing a landing posture consistent with reduced ACL injury risk and limiting the forces the lower extremity must absorb. These findings suggest that clinical techniques to increase plantar-flexor extensibility and dorsiflexion ROM may be important additions to ACL injury-prevention programs.

Key Words: flexibility, extensibility, kinematics, kinetics, anterior cruciate ligament, force attenuation

Key Points

- Greater passive ankle-dorsiflexion range of motion was associated with greater knee-flexion displacement and smaller ground reaction forces during landing, which may be associated with a reduced risk of anterior cruciate ligament injury.
- Increasing plantar-flexor extensibility and dorsiflexion range of motion may help to reduce anterior cruciate ligament loading.
- Clinical measures of dorsiflexion range of motion may be helpful in identifying individuals at increased risk of anterior cruciate ligament injury.

Anterior cruciate ligament (ACL) injury typically occurs during athletic participation via a noncontact mechanism involving planting, pivoting, or landing (or a combination of these).[1] A smaller amount of knee-flexion displacement, greater knee-valgus displacement, and greater vertical and posterior ground reaction forces during landing purportedly increase ACL loading and injury risk.[2–4] These biomechanical factors are interrelated, in that "stiff" landings characterized by an erect landing posture and less sagittal-plane displacement result in greater ground reaction forces than a more flexed landing posture.[5,6] Similarly, greater ground reaction forces are associated with greater knee-valgus displacement and moment.[2]

The joints of the lower extremity function in concert in the sagittal plane to attenuate landing forces, such that greater motion at one joint is typically accompanied by greater motion at adjacent joints.[5,7,8] Although most authors studying ACL injury and landing biomechanics have focused on the knee and hip, considerably less attention has been devoted to the ankle. The ankle plantar flexors play a substantial role in the absorption of landing forces,[5,9] and a smaller amount of sagittal-plane ankle displacement (dorsiflexion) during landing results in greater peak landing forces.[5,8,10] Additionally, the sagittal-plane coupling of the lower extremity joints[5,7] suggests that less dorsiflexion displacement during landing is accompanied by less knee-flexion and hip-flexion displacement.

This notion is supported by Kovacs et al,[8] who reported greater vertical ground reaction forces and smaller dorsiflexion, knee-flexion, and hip-flexion displacements during heel-to-toe landings than with forefoot-first landings. Hagins et al[11] restricted the available dorsiflexion range of motion (ROM) during landing by having participants land on an inclined surface and reported greater knee-valgus displacement and posterior ground reaction forces compared with landing on a flat surface that permitted full dorsiflexion displacement. Similarly, Sigward et al[12] demonstrated that individuals with less passive dorsiflexion ROM demonstrated greater knee-valgus excursion during landing. Furthermore, Bell et al[13] noted that medial knee displacement (valgus) during a controlled squatting task was diminished when the available dorsiflexion ROM was increased by placing a wedge under the calcaneus, indicating that dorsiflexion ROM influences frontal-plane knee motion. In combination, these results suggest that restricted dorsiflexion ROM may increase ACL loading and injury risk via association with less knee-flexion displacement, greater knee-valgus displacement, and greater ground reaction forces during landing.

Ankle-dorsiflexion ROM can be increased via a variety of training and clinical techniques.[14–16] Thus, dorsiflexion ROM is a modifiable factor that may serve as a mechanism by which ACL injury risk can be attenuated. Yet how clinical measures of dorsiflexion ROM influence landing biomechanics is unclear. The report from the most recent consensus meeting on noncontact ACL injuries indicated that "little data exist regarding the feasibility and effectiveness of screening the 'at-risk' population."[4(p1527)] Identifying clinically based assessments that discriminate this at-risk population would be invaluable for ACL injury-prevention efforts. Therefore, the purpose of our investigation was to evaluate the relationships between clinical measures of dorsiflexion ROM and knee-flexion displacement, knee-valgus displacement, and vertical and posterior ground reaction forces during landing. We hypothesized that greater dorsiflexion ROM would be associated with (1) smaller vertical and posterior ground reaction forces, (2) less knee-valgus displacement, and (3) greater knee-flexion displacement, thereby placing the lower extremity in a position consistent with reduced ACL loading and injury risk.

METHODS

Participants

Thirty-five physically active individuals (17 men, 18 women; age = 20.5 ± 1.5 years, height = 1.7 ± 0.1 m, mass = 73.4 ± 14.1 kg) volunteered for this study. Exclusion criteria (determined by questionnaire) were existing neurologic and lower extremity chronic conditions, history of acute lower extremity injury within the 6 months before data collection, and history of lower extremity surgery. All data were collected in a single testing session, and all procedures were conducted on the *dominant leg*, defined as the leg used to kick a ball for maximum distance. All participants read and signed an approved informed consent document before data collection. The study was approved by the university's institutional review board.

Procedures

Passive ankle-dorsiflexion ROM was measured in 2 positions (extended knee and flexed knee) using a standard manual goniometer. For the extended-knee assessment, volunteers were seated on a treatment table with the knees fully extended (0°) and the feet hanging off the end of the table. For the flexed-knee assessment, they were seated with the popliteal space at the edge of the table and the knees in 90° of flexion. Goniometric measurements were taken to confirm proper knee-flexion angles before ROM measurements. For each ROM measurement, the participant was completely relaxed; the investigator passively moved the ankle into dorsiflexion from a neutral starting position (ie, 90° angle between shank and foot segments) until a firm end feel was elicited. The axis of the goniometer was centered over the lateral malleolus and the arms were aligned with the fibular shaft and the head of the fifth metatarsal. Five measurements were taken in each position. All ROM measurements were collected by the same investigator (C.M.F.), and analysis of these data revealed high reliability and precision across trials (extended-knee assessment: intraclass correlation coefficient [3,1] = 0.90, standard error of measurement = 1.8°; flexed-knee assessment: intraclass correlation coefficient [3,1] = 0.84, standard error of measurement = 2.6°).

Lower extremity biomechanical data were sampled during a landing task using a 7-camera motion-capture system (Vicon Motion Systems, Centennial, CO) interfaced with a force plate (Bertec Corporation, Columbus, OH). Participants were fitted with spandex shorts and shirt, and 25 retro-reflective markers were applied bilaterally over the acromion processes, anterior-superior iliac spines, greater trochanters, anterior thighs, medial and lateral femoral epicondyles, anterior shanks, medial and lateral malleoli, calcaneus, and first and fifth metatarsal heads using double-sided tape; a single marker was placed on the sacrum. Markers used to represent anatomical landmarks on the foot segment were placed over the volunteer's shoes in estimated locations. Markers were digitized from a static trial during which the participant stood as motionless as possible with the arms abducted to 90° to create a segment-linkage model of the lower extremity. Knee-joint and ankle-joint centers were defined as the midpoints between markers on the medial and lateral epicondyles and malleoli, respectively. These medial markers were then removed for landing trials. The location of the hip-joint center was estimated from the digitized markers on the left and right anterior-superior iliac spine as described by Bell et al.[17]

Landing trials began with participants standing atop a box 30 cm in height placed 40% of the person's height from the leading edge of the force plate. He or she was instructed to jump off the box horizontally and land on both feet, with the dominant foot positioned on the force plate. This task represents a hybrid of the drop landing[6,18] and the jump landing[3] used in previous research because we wanted to target characteristics of both maneuvers. Specifically, the drop jump is primarily vertical in nature; thus, it does not mimic the horizontal-loading components that typically accompany dynamic tasks. Additionally, muscle activity during the jump landing is used to resist the downward acceleration of the body and to produce lower extremity extension to propel the body upward on the

Table 1. Dependent Variable Descriptive Statistics

Variable	Mean ± SD
Ankle-dorsiflexion range of motion, °	
Extended knee	14.3 ± 5.5
Flexed knee	18.9 ± 5.9
Knee-flexion displacement, °	69.1 ± 12.0
Knee-valgus displacement, °	7.0 ± 5.0
Vertical ground reaction force, × body weight	2.2 ± 0.6
Posterior ground reaction force, × body weight	0.6 ± 0.2

subsequent vertical leap. Because we were especially interested in the loading phase of the landing and how dorsiflexion ROM influenced landing biomechanics during this phase, we chose to include only the landing portion of the jump landing so that any associated muscle activity would be used for controlling downward acceleration. Volunteers were allowed up to 3 practice trials to familiarize themselves with the task. Lower extremity kinematics and kinetics were sampled during the jump-landing task, with the first 5 successful trials used for data analysis. Unsuccessful trials occurred when participants landed with any portion of the dominant foot off the force plate or lost their balance after landing; these trials were discarded and repeated until 5 successful trials were obtained.

Data Sampling and Reduction

Kinematic and kinetic data were sampled at 150 Hz and 1500 Hz, respectively, and time synchronized using Vicon Nexus motion-capture software (Vicon Motion Systems). Raw 3-dimensional marker coordinates and ground reaction forces were imported into MotionMonitor software (Innovative Sports Training, Inc, Chicago, IL) and low-pass filtered at 10 Hz (fourth-order Butterworth). The global axis system was established such that the positive x-axis, y-axis, and z-axis represented forward, left, and upward directions, respectively. Knee-joint angles were calculated as Euler angles (YXZ sequence), defined as motion of the shank reference frame relative to the thigh reference frame. Knee-flexion and knee-valgus displacements and peak vertical and posterior ground reaction forces were identified during the loading phase of landing using custom software (LabVIEW, National Instruments Corporation, Austin, TX). The *loading phase* was defined as the time interval between initial ground contact and peak knee flexion, with *initial ground contact* identified as the instant at which the vertical ground reaction force exceeded 10 N. Ground reaction force data were normalized to body weight before statistical analysis.

Statistical Analysis

All dependent variables were averaged over the 5 trials for use in statistical analyses. Eight separate Pearson bivariate correlation analyses were conducted to evaluate the relationships between ankle-dorsiflexion ROM in the 2 positions (4 analyses per position) and knee-flexion displacement, knee-valgus displacement, and peak vertical and posterior ground reaction force, respectively. Statistical significance was established a priori as $\alpha \leq .05$.

Table 2. Correlations for Extended-Knee Ankle-Dorsiflexion Range of Motion

Criterion Variable	*r*	*P* Value
Knee-flexion displacement	0.464	.029[a]
Knee-valgus displacement	−0.290	.091
Vertical ground reaction force	−0.411	.014[a]
Posterior ground reaction force	−0.412	.014[a]

[a] Indicates significant correlation between variables.

RESULTS

Descriptive statistics for all dependent variables are presented in Table 1. Correlation coefficients and probability statistics for the extended-knee and flexed-knee dorsiflexion ROM assessments are presented in Tables 2 and 3, respectively. Significant correlations were observed between extended-knee dorsiflexion ROM and knee-flexion displacement ($r = 0.464$, $P = .029$), vertical ground reaction force ($r = -0.411$, $P = .014$), and posterior ground reaction force ($r = -0.412$, $P = .014$). The correlation for knee-valgus displacement was nonsignificant ($r = -0.290$, $P = .091$). All correlations between flexed-knee dorsiflexion ROM and the biomechanical variables of interest were nonsignificant ($P > .05$).

DISCUSSION

Greater passive ankle-dorsiflexion ROM was associated with greater knee-flexion displacement and smaller ground reaction forces during landing. These biomechanical factors are considered risk factors for ACL injury,[2–4] so the findings indicate that techniques designed to increase plantar-flexor extensibility and dorsiflexion ROM may attenuate ACL injury risk by placing the lower extremity in a position consistent with reduced ACL loading, thus decreasing the forces the lower extremity must absorb after ground contact. Additionally, clinical measures of dorsiflexion ROM may be important components of screening efforts to identify individuals at greater risk for ACL injury.

The relationships between extended-knee dorsiflexion ROM and knee-flexion displacement and ground reaction forces are in agreement with our hypotheses: Individuals who displayed greater dorsiflexion ROM demonstrated smaller ground reaction forces and greater knee-flexion displacement. These findings are consistent with those of Kovacs et al,[8] who evaluated the influence of foot position on landing biomechanics by having volunteers land in heel-to-toe versus forefoot-first maneuvers. Heel-to-toe landings resulted in less sagittal-plane displacement at the ankle, knee, and hip and greater vertical ground reaction forces. Supplementary correlational analyses of our data indicated that greater extended-knee dorsiflexion ROM also was correlated with greater hip-flexion displacement ($r = 0.357$,

Table 3. Correlations for Flexed-Knee Ankle-Dorsiflexion Range of Motion

Criterion Variable	*r*	*P* Value
Knee-flexion displacement	0.327	.055
Knee-valgus displacement	−0.330	.053
Vertical ground reaction force	−0.311	.069
Posterior ground reaction force	−0.295	.085

P = .035) but not ankle-dorsiflexion displacement (r = 0.150, P = .391). The lack of correlation between dorsiflexion ROM and dorsiflexion displacement may be explained by between-subjects differences in landing style. Although the mean ankle angle at initial ground contact was 35° (0° = neutral, + = plantar flexion), this value varied considerably across the sample (SD = ±15°; range, 60°), suggesting that participants adopted various landing styles from a more dorsiflexed initial-contact angle, which restricts further dorsiflexion displacement, to a more plantar-flexed contact angle, which maximizes dorsiflexion displacement. These differences in landing styles could have influenced landing biomechanics (specifically dorsiflexion displacement) independent of passive dorsiflexion ROM.[8,19]

Even though extended-knee dorsiflexion ROM was significantly correlated with the biomechanical variables of interest, none of the associated correlations were significant for flexed-knee dorsiflexion ROM. The lack of association between landing biomechanics and flexed-knee dorsiflexion ROM may be explained by knee-joint kinematics during the landing and the contribution of the gastrocnemius muscle to force attenuation. The mean knee-flexion angle at initial ground contact was 11.1° ± 6.6°; the peak value was 80.2° ± 13.3°. The extended-knee ROM measurement, performed in 0° of knee flexion, assesses the extensibility of both gastrocnemius and soleus muscles, whereas the flexed-knee measurement, performed at 90° of knee flexion, essentially isolates the soleus.[20,21] Therefore, the extended-knee testing position is likely a better indication of the ROM restrictions placed on dorsiflexion displacement during the landing task. Because the gastrocnemius likely contributes substantially to force attenuation within the range of knee displacement demonstrated during the landing task we used, the fact that the flexed-knee dorsiflexion ROM excludes contributions of the gastrocnemius likely explains the lack of correlation with landing biomechanics.

It is worth noting that although none of the correlations between flexed-knee dorsiflexion ROM and landing biomechanics were significant, these correlations all approached significance (P values = .053 to .085), suggesting statistical trends. We, therefore, conducted post hoc power analyses, which revealed observed powers of 0.51 for knee-flexion displacement, 0.51 for knee-valgus displacement, 0.38 for vertical ground reaction force, and 0.46 for posterior ground reaction force, indicating that 68, 66, 96, and 75 participants, respectively, would be required to achieve statistical power of 0.80 for $\alpha = .05$. These analyses suggest that a larger sample size might have resulted in significant findings and support the need for future research regarding the influence of dorsiflexion ROM on ACL injury risk factors.

The lack of association between dorsiflexion ROM and knee-valgus displacement during the landing task was contrary to our initial hypothesis. Bell et al[13] reported that valgus motion during a controlled squatting task was diminished when slack was introduced to the plantar-flexor musculature by placing a wedge under the calcaneus, thus increasing the available dorsiflexion ROM. Using a more dynamic landing task, Hagins et al[11] induced greater knee-valgus displacement and posterior ground reaction forces when they reduced the available dorsiflexion ROM by having volunteers land on an inclined surface, rather than on a flat surface, which permitted full dorsiflexion displacement. Similarly, Sigward et al[12] demonstrated a negative correlation between dorsiflexion ROM and frontal-plane knee excursion during landing. Based on these results, we hypothesized that individuals who demonstrated less ankle-dorsiflexion ROM would display greater knee valgus during the landing task. However, our results were contrary to our hypotheses, likely due to a number of factors. The inclusion criteria used by Bell et al[13] to identify volunteers may partially explain the discrepancies in the studies' findings. These authors screened potential participants to try to identify individuals who demonstrated a reduction in medial knee displacement (MKD) when performing the squat task on the wedge versus a flat support surface. Only 18 of 75 (24%) of the potential volunteers met this criterion and were assigned to the MKD group. In addition, Bell et al[13] reported a mean of 8.5° for passive extended-knee dorsiflexion ROM in the MKD group, whereas the mean for our sample was 14.3°, a difference of approximately 40%. These discrepancies suggest that dorsiflexion ROM may only influence frontal-plane knee motion in a limited percentage of individuals who possess extreme ROM restrictions. It is also unclear if the demands placed on the lower extremity joints are comparable between the controlled squatting task used by Bell et al[13] and the more dynamic landing task in our investigation. Furthermore, the MKD sample investigated by Bell et al[13] consisted of 3 men and 15 women. Numerous investigators[22–24] have reported greater knee valgus in women than in men during a variety of tasks; thus, a sample composed primarily of women may have enhanced their ability to identify an effect of dorsiflexion ROM on knee valgus in comparison with our more balanced sample (17 men, 18 women). Additionally, although Hagins et al[11] used a similar landing task, they experimentally manipulated landing kinematics by altering the landing surface and evaluated differences between conditions via a repeated-measures design, whereas our analyses were correlational in nature and evaluated the inherent available dorsiflexion ROM. The greater statistical strength afforded by the repeated-measures design and experimental manipulation of dorsiflexion ROM may have enhanced their ability to identify an effect of dorsiflexion ROM on knee valgus, and the relatively limited power of correlation analyses may have impeded our ability to do so. More important, differences in the samples tested in these investigations also may account for discrepancies: Hagins et al[11] studied a homogeneous group of professional dancers, whereas we studied a more heterogeneous group of individuals who met minimal physical activity criteria (at least 20 minutes of physical activity a minimum of 3 times per week). Although Hagins et al[11] did not report mean and SD values for joint kinematics, it is likely that their homogeneous sample of professional dancers demonstrated similar landing styles and kinematics as a function of common prior training compared with the highly variable landing styles and kinematics in our sample, as evidenced by the ankle angle at initial ground contact. Last, differences in landing tasks (vertical drop landing versus horizontal jump landing), jump heights (46 cm versus 30 cm), knee position during dorsiflexion ROM measurements (30° versus 0° and 90°), and samples (women soccer players versus men and women recreational athletes) between the study of Sigward et al[12] and ours likely explain the discrepancies in findings. It is again worth noting that the correlation between knee-flexed dorsiflexion ROM and knee valgus approached statistical significance, suggesting a trend.

The correlations between dorsiflexion ROM and hip and knee displacements indicate that greater dorsiflexion ROM is associated with a less-erect posture during landing and greater sagittal-plane joint displacement. Increased sagittal-plane joint displacement of the lower extremity increases the duration of the loading phase, allowing landing forces to be dissipated over a longer time interval, resulting in smaller peak forces (ie, enhanced force attenuation).[5,25] Therefore, the negative relationship between ankle-dorsiflexion ROM and ground reaction forces is likely a consequence of the enhanced force-attenuation capacity afforded by greater sagittal-plane displacement.

Immediately after ground contact, the knee is forced into flexion by vertical and posterior ground reaction forces and downward acceleration of the body's center of mass. These landing forces can exceed 10 times body weight[26] and have been suggested as important factors in determining ACL loading and injury risk. Hewett et al[2] demonstrated prospectively that landing forces were 20% greater in individuals who sustained ACL injuries than in an uninjured cohort. Furthermore, ground reaction forces indicate anterior tibial acceleration[27] and shear force[3] during landing, factors that directly contribute to ACL loading.[28,29] Excessive quadriceps activity has also been suggested as a risk factor for ACL injury: cadaveric[30,31] and in vivo[32] research showed that quadriceps activation produces ACL loading and injury in vitro.[33] Landing in a less-erect posture decreases quadriceps activity[6] and encourages longer muscle moment arms in the lower extremity, thus reducing the muscular-force requirements to attenuate landing forces compared with a more-erect landing posture.[5] The correlations between greater dorsiflexion ROM, greater sagittal-plane displacements, and smaller landing forces in our data and the likely influence on quadriceps activity suggest that ankle-dorsiflexion ROM may play an important role in the expression of ACL injury risk factors.

Our study provides novel information regarding how clinical measures of dorsiflexion ROM are associated with biomechanical variables suggested as ACL injury risk factors. These results both support and extend previous research in that our ROM measures represent those typically used in the clinical setting (ie, 0° and 90° of knee flexion versus 30° for Sigward et al[12]) and are generalizable to a broader segment of the population (ie, men and women recreational athletes versus women soccer players[12] versus individuals who met specific medial knee-displacement criteria[13]). Because ankle-dorsiflexion ROM can be enhanced via a variety of clinical and training mechanisms,[14–16] implementing techniques to increase plantarflexor extensibility and dorsiflexion ROM may be important additions to future ACL and lower extremity injury-prevention programs. However, the clinical application of these results should be approached with caution, given that a limitation of this investigation is its correlational design. The results do not suggest that greater ankle-dorsiflexion ROM causes modifications of landing posture and ground reaction forces consistent with reduced ACL injury risk but rather that these factors are simply correlated. Yet our findings provide rationale for and inform the development of future investigations to evaluate the influence of interventions designed to increase dorsiflexion ROM on landing biomechanics and ACL injury risk factors. Additionally, the fact that clinical measures of dorsiflexion ROM were associated with ACL injury risk factors indicates that these measures may be important factors to consider when implementing screening efforts to identify individuals at greater risk of ACL injury. Future prospective researchers should evaluate the ability of dorsiflexion ROM measures to discriminate ACL-injured versus uninjured cohorts as well as the effects of interventions designed to increase dorsiflexion ROM on ACL injury risk.

The post hoc power analyses indicate the possibility that inadequate sample size limited our ability to identify relationships between dorsiflexion ROM and landing biomechanics. Additionally, the strength of the significant correlations in our data was low to moderate, with knee-extended dorsiflexion ROM explaining only 22%, 17%, and 17% of the variance in knee-flexion displacement, vertical ground reaction force, and posterior ground reaction force, respectively. Therefore, although dorsiflexion ROM appears to influence landing biomechanics, a large portion of the variance in these biomechanical ACL injury risk factors is explained by other factors. Specifically, we did not evaluate electromyographic activity of the lower extremity during the landing task. Because greater activity of the extensors, particularly the quadriceps, results in larger ground reaction forces and less knee flexion during landing,[6] a portion of the variance in landing biomechanics was likely attributable to variance in these factors. Furthermore, ground reaction forces and knee flexion during landing are influenced by trunk motion[6]; thus, a portion of the unexplained variance is probably attributable to trunk kinematics as well. Last, knee flexion and ground reaction forces are influenced by ankle position at initial ground contact.[8] Our participants exhibited a large range of values for ankle position at initial ground contact (60°), so the inconsistency in this contributor to landing biomechanics likely limited the strength of the correlations.

An additional limitation of our investigation is that we did not obtain information regarding our volunteers' previous history of ankle injury. Kramer et al[34] demonstrated an association between previous history of ankle injury and ACL injury risk. Ankle instability influences landing kinematics and kinetics,[35,36] but it is unclear how a history of ankle injury might have influenced our results. Moreover, restricted dorsiflexion ROM is associated with a greater risk of patellar tendon injury[37]; therefore, future research regarding dorsiflexion ROM interventions on a variety of lower extremity injuries may be warranted. Finally, a limited body of knowledge exists regarding the influence of artificial restrictions of dorsiflexion ROM (eg, taping and bracing) on landing biomechanics.[38] As a result, future investigators should also evaluate these influences to identify the consequences for the proximal joints of the lower extremity.

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