SCIENTIFIC JOURNAL OF SPORT AND PERFORMANCE

ORIGINAL ARTICLE

Exploring ACL risk factors differences between quick and max drop jump

Maya Caon . *Department of Health Sciences and Clinical Practice. Barry University. Miami Shores, United States of America.*
Tal Amasay. *Department of Health Sciences and Clinical Practice. Barry University. Miami Shores, United States of America.*
David Suprak. *Department of Kinesiology and Physical Education. Western Washington University. Bellingham, United States of America.*
Claire Egret. *Department of Health Sciences and Clinical Practice. Barry University. Miami Shores, United States of America.*
Nathaniel Boiangin. *Department of Health Sciences and Clinical Practice. Barry University. Miami Shores, United States of America.*

ABSTRACT

Anterior cruciate ligament (ACL) tears in most common in female athletes often occur during rapid/reactive landings. Although drop jumps are commonly used to assess ACL injury risk, it remains unclear which type is more sensitive to detecting high-risk movement patterns. The purpose of this study was to investigate which of the two types of drop jumps, max vertical jump (DMVJ) and quick vertical jump (DQVJ), is more sensitive identifying ACL injury risk factors. Forty-three NCAA Division II female athletes participated in the study. The participants completed three trials of each drop jump while kinematics, kinetics, and EMG data were collected. Paired t-tests or Wilcoxon tests with Holm–Bonferroni correction ($\alpha = .05$) were used for analysis. Lower knee flexion, knee adduction angles were observed at DQVJ ($p < .05$). DQVJ showed higher peak knee abduction angular velocity, peak vertical ground reaction force BW, and maximal rate of force development ($p < .05$). Muscle activity was also greater in DQVJ, for the semitendinosus and vastus lateralis muscles ($p < .05$). The DQVJ elicited stiffer landings, increased frontal-plane knee motion, and altered VL–ST activation, supporting its use as a sensitive and practical tool for identifying ACL-risk mechanics in female athletes.

Keywords: Sport medicine, Anterior cruciate ligament (ACL), Landing biomechanics, Knee valgus, Drop-jump, Electromyography, Female athletes.

Cite this article as:
Caon, M., Amasay, T., Suprak, D., Egret, C., & Boiangin, N. (2026). Exploring ACL risk factors differences between quick and max drop jump. *Scientific Journal of Sport and Performance*, *5*(1), 106-117. https://doi.org/10.55860/ASMY2885

Corresponding author. *Barry University, Department of Health Sciences and Clinical Practice. 11300 NE 2nd Avenue, Miami Shores, FL 33161, United States of America.*
E-mail: mayacaon@gmail.com
Submitted for publication September 08, 2025.
Accepted for publication October 09, 2025.
Published October 24, 2025.
Scientific Journal of Sport and Performance. ISSN 2794-0586.

doi: https://doi.org/10.55860/ASMY2885

INTRODUCTION

The anterior cruciate ligament (ACL) is the primary restraint to anterior tibial translation and a key restriction of rotary motion at the knee. However, it often tears during jump-landing, cutting, and pivoting maneuvers (Hewett et al., 2006). In 2012, the National Collegiate Athletic Association (NCAA) reported that more than 2,000 ACL tears occur annually among collegiate athletes across 15 high-risk sports, with the incidence increasing by 1.3% per year over the previous 16 years (NCAA, 2012). Moreover, the financial burden is substantial, with direct surgical costs averaging approximately $9,400 and perioperative care exceeding $13,000. When combined with meniscal or collateral ligament repairs, total expenses can reach up to $20,000 (Herzog et al., 2017). In addition, radiographic evidence of osteoarthritis has been reported in up to 50% of individuals within ten years following injury (Freedman et al., 1998). Beyond the physical consequences the psychological impact of prolonged rehabilitation can be significant, often contributing to anxiety, depression, and a diminished athletic identity (Putukian, 2016).

From 2014-2019, the NCAA logged 729 ACL tears in 8.47 million athlete-exposures (A-Es), a rate of 0.86 per 10,000 A-Es; tears were five times more likely to occur in competition than in practice (Dewig et al., 2024). Sport and sex specific rates highlight the disparity where women's soccer tops all at 2.60 per 10,000 A-Es, while men's football tops male sports at 1.44 per 10,000 A-Es. Other high-risk women's sports include basketball (1.74), gymnastics (1.77), and lacrosse (1.50), whereas men's lacrosse follows football at 1.10 per 10,000 A-Es (Dewig et al., 2024). Women suffer ACL tears four to six times more often than men in comparable sports, for example, women's basketball has an injury-rate ratio (IRR) of 3.62 and women's soccer an IRR of 2.77, versus men's. Contact mechanisms dominate men's ACL tears, whereas non-contact mechanisms prevail in women (Dewig et al., 2024). Long-term surveillance of ACL injuries shows rising rates in most cutting and pivoting sports, despite modest declines in events like women's gymnastics (Agel et al., 2016).

ACL injury risk factors are classified as extrinsic (environmental or situational) or intrinsic (athlete-specific), with intrinsic factors further divided into modifiable and non-modifiable (Murphy et al., 2003). Non-modifiable risk factors, such as increased Q-angle, joint laxity, and hormonal fluctuations, cannot be changed (Pfeifer et al., 2018). Modifiable factors, including biomechanical and neuromuscular imbalances, can be targeted by training interventions, making them particularly important for injury prevention programs. One such imbalance, ligament dominance, occurs when athletes rely excessively on passive knee structures rather than active muscular stabilization, resulting in excessive knee abduction (valgus) during landing (Hewett et al., 2010). Similarly, quadriceps dominance, characterized by aggressive quadriceps contractions and insufficient hamstring activation, can produce increased anterior tibial translation and ACL strain during landing maneuvers (Dauty et al., 2022; Hewett et al., 2010). These neuromuscular imbalances are especially prevalent among female athletes, contributing to their higher ACL injury rates (Hewett et al., 2006).

Electromyography (EMG) studies have highlighted the importance of neuromuscular control deficits immediately preceding initial ground contact (IC) as predictors of ACL injuries. Zebis et al. (2009) demonstrated that athletes who subsequently suffered ACL ruptures exhibited significantly reduced semitendinosus (ST) pre-activation, approximately 21% of the peak muscle activation recorded during the entire jump movement, and heightened vastus lateralis (VL) pre-activation, approximately 69% of the peak muscle activation during the same jump movement, measured within the 10 milliseconds before landing. Such neuromuscular imbalances impair muscular stabilization at the knee, reducing the hamstrings' ability to counteract the anterior tibial translation and internal rotation caused by strong quadriceps contractions (Zebis et al., 2008).

Biomechanical analyses of actual ACL injury events consistently indicate that ruptures typically occur within 30–50 milliseconds following IC, a critical timeframe marked by rapid increases in knee valgus angle (inward knee collapse), internal tibial rotation, and high vertical impact forces (Koga et al., 2010; Krosshaug et al., 2007) . Koga et al. (2010) observed rapid valgus collapse averaging approximately 12° within the first 40 ms after initial contact implying a high frontal-plane angular velocity. In a cadaveric and in-vivo study, results indicated that knee abduction angular velocity, not the final valgus angle, is the primary driver of ACL load. In a drop-landing simulation, peak ACL strain occurred exactly when valgus angular velocity peaked (~70°·s^{-1}, 45 ms post-IC) (Kiapour et al., 2014). Additionally, an in-vivo study showed that internally rotated landings produced higher valgus angular velocities than neutral landings, implying greater risk for ACL injury (Shinde et al., 2022). Hewett et al. (2005) conducted a prospective cohort study on 205 female soccer, basketball, and volleyball players using 3D motion analysis and force plates during a drop vertical jump (DVJ) task. In this study the athletes were screened once, during pre-season, and they were then followed through the competitive season, during which nine of them sustained ACL injuries. Injured athletes exhibited significantly greater knee abduction angles at initial contact, 8.4° higher than uninjured athletes, as well as a 7.6° greater maximum knee abduction angle. Additionally, they demonstrated increased medial knee displacement during landing, indicating more pronounced dynamic valgus. These athletes also showed approximately 20% higher peak vertical ground reaction forces (vGRF). Rapid force application, reflected in high peak vGRF and a steep rate of force development (RFD), were associated with stiffer landings, limiting the muscles' ability to absorb impact effectively and thereby increasing ACL injury risk (Hewett et al., 2005; Yu et al., 2006).

The drop vertical jump (DVJ), typically performed from a 31 cm box, is commonly used to assess biomechanics variables associated with ACL injury risk factors (Ford et al., 2003; Hewett et al., 2005). However, most research has concentrated on controlled landing conditions, neglecting muscle pre-activation patterns and rapid force application present in more reactive jumps. Peng et al. (2011) and Yu et al. (2006) showed that increased landing stiffness and greater vGRF during drop landings were associated with higher ACL strain, suggesting that dynamic variations of landing tasks could further amplify risk markers. In this context, our study compared two distinct types of drop jumps, the drop-to-quick vertical jump (DQVJ), emphasizing immediate rebound and rapid force absorption, and the drop-to-maximal vertical jump (DMVJ), which involves more controlled landings aimed at maximizing jump height. Since sport-specific movements often involve rapid reactive tasks resembling the DQVJ, it was essential to compare both jump variations to identify which one is more sensitive to biomechanical and neuromuscular ACL injury risk factors. Moreover, female athletes are more susceptible to non-contact anterior cruciate-ligament (ACL) tear, three- to six-folds, than men. Sex-specific neuromuscular and biomechanical features contribute to this increase risk (Hewett et al., 2006; Quatman & Hewett, 2009), and therefore justify the focus of this study to investigate knee abduction angles at critical time points (IC, peak stance, 40–50 ms post-IC), eccentric knee-abduction angular velocity, maximal knee flexion, peak vertical ground reaction force, maximal rate of force development, and pre-activation of the VL and ST muscles between the two drop jumps, DQVJ and DMVJ, in collegiate women athletes.

This study's outcomes aimed to enhance ACL injury risk screening by identifying which jump task more clearly reveals critical deficits in knee mechanics and neuromuscular activation. Improved detection of at-risk athletes allows coaches, trainers, and clinicians to implement targeted interventions aimed at reducing ACL injury incidence, mitigating the associated physical, psychological, and financial burdens.

MATERIAL AND METHODS

Participants

Forty-three female NCAA Division II athletes from Barry University volunteered for the study (mean ± SD): age 20.93 ± 2.00 y; height 167.44 ± 7.10 cm; body weight 65.50 ± 13.39 kg; total body fat 22.70 ± 6.15 % (Table 1). The University Institutional Review Board approved all procedures. Before data collection each participant provided written informed consent and completed a brief questionnaire covering demographics, competitive history, strength and conditioning background, and lower/upper body injuries sustained in the past year that could compromise maximal-jump performance. Inclusion criteria were: (i) female NCAA DII roster status, (ii) age ≥ 18 years, (iii) ≥ 3 years of continuous competitive experience in their sport, (iv) current medical clearance from the university athletic-training staff, and (v) no lower-limb surgery or musculoskeletal injury within the last 12 months. Athletes with neurological, musculoskeletal, or cardiovascular conditions that contraindicated maximal jumping were excluded. Recruitment was conducted through informational flyers and direct conversations with athletes.

Table 1. Demographic descriptives (N = 43).

	Age	Height (cm)	Weight (kg)	Total BF (%)
Mean	20.93	167.44	65.50	22.70
Standard deviation	2.00	7.10	13.39	6.15
Minimum	18	153.00	48.60	10.80
Maximum	29	183.00	133.70	45.00

Measures

Body composition was measured with participants barefoot and lightly clothed on a multi-frequency segmental bio-impedance analyzer (MC-780U, Tanita, Tokyo, Japan). Next, reference maximum jump height was established on a Vertec device after a standardized warm-up (detailed in the next section); out of three maximal countermovement jumps, the highest jump was recorded. Motion capture and force data were collected and synchronized in Noraxon MR4 software (v4.0.4). Seven inertial measurement units (MyoMotion, Noraxon USA Inc.) sampled at 200 Hz were placed on the pelvis (S2), left/right thighs (at 75% of femur length), left/right shanks (75% of tibia length), and left/right dorsal mid-feet. A standard standing and walking calibration trial, as provided by Noraxon's protocol, was used to initialize the joint coordinate system; all reported joint angles represent excursions (Δ°) from this reference. Ground-reaction forces were recorded and collected using two AMTI force plates (Boston, MA, USA) at 1,000 Hz, filtered at 20 Hz, and peak vertical ground-reaction force (vGRF) was normalized to body weight (BW). Electromyography (EMG) data were collected using wireless Ultium EMG sensors (Noraxon) placed bilaterally on the vastus lateralis (VL; 75% of thigh length) and semitendinosus (ST; 50% of thigh length,). EMG signals were sampled at 2,000 Hz, band-pass filtered from 10–500 Hz, rectified, and smoothed using a 50 ms root mean square (RMS) window. Pre-activation was quantified as the highest EMG amplitude recorded during the last 10 ms before initial ground contact (IC). This value was then normalized to the maximum EMG amplitude observed in the same trial, and reported as a percentage of that peak (Zebis et al., 2009).

Procedures:

Warm-up and preparation

After signing consent, participants completed a five-minute self-paced warm-up on a cycle ergometer, followed by a five-minute dynamic routine consisting of one set of 10 repetitions each of high knees, butt kicks, squats, side lunges (5 per side), and power skips to activate the lower limbs (Schmorantz et al., 2024). Maximal jump height was then determined using three countermovement jumps on a Vertec device, separated by two-minute rest periods; the highest jump was recorded for each participant. Participants then completed at least three familiarization trials of each drop-jump variation (quick and maximal), with additional trials performed if needed. Following familiarization, EMG electrodes and Noraxon MyoMotion IMUs were positioned as previously described.

Drop-jump test

A 31 cm box was positioned just behind the two force plates, with Vertec vanes aligned directly above the plates. The order of jump conditions was randomized. For each trial, participants stepped off the box, landed with each foot on separate force plate, and performed a vertical jump. In the Drop to Quick Vertical Jump (DQVJ), participants were instructed explicitly to jump as quickly as possible upon landing, aiming for a target height set at 75% of their previously measured maximum jump height. The 75% height was selected based on previous findings by Amasay and Suprak (2022), indicating that this specific height is optimal for eliciting rapid reactive jumps. In contrast, during the Drop to Maximal Vertical Jump (DMVJ), participants were instructed to jump as high as possible, aiming for a height corresponding to at least 90% of their maximal jump height. This 90% threshold was chosen to encourage maximal effort without causing discouragement, ensuring participants consistently jumped at or near their maximum capacity. A jump attempt was considered valid only if the participant landed with each foot completely on separate force plates, both during the initial drop and after the vertical jump. Additionally, post-landing balance had to be maintained without compensatory movements, such as stumbling or taking extra steps. Rest intervals were at least 30 seconds between individual jumps and at least two minutes between jump conditions. Three valid attempts per condition were recorded, and the best trials, defined as the shortest ground contact time for the DQVJ and the highest jump height for the DMVJ, were recorded for subsequent analysis.

Data processing and statistical analysis

The independent factor was jumping condition, DQVJ and DMVJ. Kinematic, kinetic, and neuromuscular variables were analyzed separately for the right and left legs; no adjustments were made for limb dominance or directionality, and each leg was treated as an independent observation. Kinematic variables were knee adduction/abduction angle at initial contact (IC), at peak knee flexion, and at 40–50 ms post IC; knee adduction/abduction angle change from IC to peak knee flexion; peak knee flexion angle; and peak knee abduction angular velocity observed during the eccentric phase. Kinetic variables were peak vertical ground reaction force (vGRF) and maximal rate of force development (RFD). Neuromuscular outcomes were the vastus lateralis and semitendinosus pre-activation amplitudes during the final 10 ms before IC. These values were expressed as a percentage of each muscle’s peak activation during the jump trial (%MVC_peak), allowing for within-trial normalization and comparison across conditions.

Raw signals were processed in Noraxon MyoResearch MR4. Each outcome’s distributions were checked with the Shapiro–Wilk normality test ($\alpha = .05$). Variables that met the normality assumption ($p > .05$) were presented as mean ± SD; variables that violated normality are reported as median and inter-quartile range (IQR). Normally distribute paired outcomes were compared with paired-sample t-test and non-normally distributed outcomes were compared using Wilcoxon signed-rank tests. To keep the familywise error rate at $\alpha = .05$ across the ten primary comparisons, *p*-values were adjusted using the Holm–Bonferroni procedure. Effect sizes were calculated as Cohen’s *d* for normally distributed paired comparisons and rank-biserial *r* for Wilcoxon tests. Interpretation thresholds were small = 0.20 (or 0.10 for *r*), medium = 0.50 (0.30), and large = 0.80 (0.50). All statistical analyses were performed in Jamovi v2.4.44.

RESULTS

A total of 86 paired jump trials (DMVJ and DQVJ) were included in the final analysis. Nine out of ten primary outcome variables violated normality assumptions and were analyzed using Wilcoxon signed-rank tests. The only variable that met normality criteria, peak eccentric knee abduction angular velocity, was evaluated using a paired-samples t-test. All results remained statistically significant after Holm–Bonferroni correction was applied with an overall α level of .05.

Kinematics

All kinematic variables exhibited significant differences between DQVJ and DMVJ. Peak knee flexion angle was significantly lower in the DQVJ compared to the DMVJ by 10.80° (p < .001, r = .98). Knee adduction angle at initial contact was 0.75° lower in the DQVJ (p = .010, r = .32). Knee adduction angle at peak knee flexion was 3.25° lower in the DQVJ (p < .001, r = .76), and at 40–50 ms post-initial contact, it was 0.90° lower (p < .001, r = .67). The change in knee adduction angle from initial contact to peak flexion was 2.25° smaller in the DQVJ compared to the DMVJ, with the knee moving 2.05 into adduction during the DMVJ and 0.20 toward abduction during the DQVJ (p < .001, r = .56), indicating less motion into adduction and a slight shift toward abduction instead in the DQVJ. Finally, peak eccentric knee abduction angular velocity was 16.67°·s^{-1} higher in the DQVJ (p < .001, d = 0.39), see Table 2.

Table 2. Kinematics variables.

Variables	Drop max vertical jump	Drop quick vertical jump
Peak knee flexion angle	89.10° [11.42°]	78.30° [11.52°]
Knee Add angle at initial contact	9.05° [6.68°]	8.30° [5.20°]
Knee Add angle 40–50 ms post-IC	11.60° [4.22°]	10.70° [5.02°]
Knee Add angle at peak flexion	11.80° [4.67°]	8.55° [8.70°]
Knee Add/Abd change IC to peak flexion	2.05° [6.28°]	-0.20° [6.72°]
Peak eccentric knee Abd angular velocity	63.86 ± 44.19 °·s^{-1} *	80.53 ± 54.10 °·s^{-1} *

*Notes: median [IQR], * mean ± SD, (-) angle is knee abduction.*

Kinetics

As with the kinematic variables, all kinetic variables exhibited significant differences between DQVJ and DMVJ Peak vertical ground reaction force was 0.35 BW higher in the DQVJ compared to the DMVJ (p < .001, r = .70). Maximal rate of force development was also significantly greater in the DQVJ by 4,447 N·s^{-1} (p = .041, r = .25), see Table 3.

Table 3. Kinetics variables.

Variables	Drop max vertical jump	Drop quick vertical jump
Peak vertical GRF (BW)	1.79 [0.66]	2.14 [0.68]
Max rate of force development (N·s^{-1})	29 724 [18 685]	34 171 [20 283]

Notes: median [IQR].

Neuromuscular activation

Consistent with kinematic and kinetic variables, neuromuscular variables exhibited significant differences between DQVJ and DMVJ. Semitendinosus pre-activation was 10.95 %MVC_peak higher in the DQVJ compared to the DMVJ (p = .007, r = .34). Vastus lateralis pre-activation was also significantly greater in the DQVJ by 5.20 %MVC_peak (p = .011, r = .32), see Table 4.

Table 4. Neuromuscular variables.

Variables	Drop max vertical jump	Drop quick vertical jump
Pre-activation vastus lateralis (%MVC_peak)	14.50 [16.03]	19.70 [19.53]
Pre-activation semitendinosus (%MVC_peak)	26.25 [33.15]	37.20 [42.92]

Notes: median [IQR]

DISCUSSION

This study investigated and compared neuromechanical factors associated with increased risk for anterior cruciate ligament (ACL) injury during the drop to maximal vertical jump (DMVJ) and the drop to quick vertical jump (DQVJ), two recognized plyometric movements. We were looking to determine which drop jump is more sensitive to identify movement patterns that are associated with increased risk of ACL injury by examining knee kinematics in the frontal and sagittal planes, peak vertical ground reaction force, rate of force development (RFD) within the ground reaction force, and pre-activation of key knee stabilizer muscles. The data show the DQVJ is more sensitive than the DMVJ in detecting both smaller and larger joint angles, forces, and muscle activations linked to ACL injury risk, likely due to its shorter ground contact and faster landing to takeoff transition. Sensitivity depends on whether the risk involves smaller or larger angle. One of the key findings in this study was the significantly reduced peak knee flexion angle during the DQVJ. Participants landed in approximately 11° less knee flexion (78.3° vs 89.1°) compared to the DMVJ, indicating a stiffer landing strategy. This aligns with Hewett et al. (2005), who reported that female athletes who later sustain ACL injuries exhibited significantly less knee flexion at landing, averaging 71.9°, compared to 81.7°in uninjured athletes. Similarly, Krosshaug et al. (2007) documented knee flexion angles as low as 67°–70° at initial contact in video analyses of actual ACL injury events. These lower flexion angles reduce the time and range available for muscular deceleration and impair the body's ability to absorb impact forces through eccentric quadriceps and hamstring activity. Consequently, more load is transferred to passive structures such as the ACL, increasing the risk of strain or rupture. This observation is consistent with Yu et al. (2006), who also identified stiffer landings as a key biomechanical risk factor for ACL injury. The consistent finding of reduced knee flexion in the DQVJ supports our hypothesis that this task better reproduces the rapid, reactive demands of sport scenarios where non-contact ACL injuries are most likely to occur.

Frontal-plane mechanics differed significantly between the two jump tasks, with greater and faster knee movement into abduction observed in the DQVJ. At initial contact, knee adduction in the DQVJ was smaller by 0.75°, placing the joint closer to abduction than the DMVJ. This difference increased to 3.3° at peak knee flexion. During the critical 40-50 ms after IC, the DQVJ knee continued to shift toward abduction, whereas the DMVJ knee stayed in an adducted orientation. The combination of lower adduction angles at landing and a greater change into abduction is clinically important, as greater knee abduction at initial contact has been shown to predict future ACL injury in prospective studies. Hewett et al. (2005) found that female athletes who later sustained ACL tears landed with knee abduction angles approximately 8.4° greater at initial contact than uninjured peers. In the present study, peak adduction was lower by 3.3° in the DQVJ, indicating greater abduction movement, and the difference remained during the 40–50 ms post contact window, a timeframe consistently associated with ACL rupture mechanisms in video-based studies (Koga et al., 2010; Krosshaug et al., 2007). Additionally, knee abduction angular velocity during the eccentric phase of landing was higher by approximately 17 $°\cdot s^{-1}$ (26% rise) in the DQVJ compared to the DMVJ. This finding reinforces emerging evidence that the speed of frontal-plane collapse, rather than just the final angle, plays a critical role in ligament strain and injury risk (Kiapour et al., 2014; Shinde et al., 2022). Important to note that these movement patterns were observed in healthy, uninjured athletes, suggesting that the DQVJ may be particularly useful for screening at risk mechanics even in the absence of injury history. Moreover, all knee angles in this study were calculated as changes from each athlete's neutral calibration posture. As a result, the data indicate the change in adduction/abduction angles with respect to the initial calibration angles and not actual angles. Consequently, we cannot discern whether a participant began in a mildly abducted posture and reduced that angle or started in adduction and moved farther into abduction. Collectively, these results suggest that dynamic frontal-plane stability changes are more emphasized during the DQVJ.

The kinetic findings suggested that DQVJ is more sensitive to ACL injury risk factors. The vertical ground reaction force (vGRF) increased from 1.79 BW in the DMVJ to 2.14 BW in the DQVJ, representing an increase of 0.35 BW, or approximately 19.6 % higher peak landing force. This aligns with the findings of Hewett et al. (2005), who reported that female athletes who later sustained ACL injuries demonstrated significantly higher vGRF during landing, averaging 1266.1 ± 149.9 N compared to 1057.8 ± 289.9 N in uninjured controls, a difference of approximately 20%. Furthermore, the maximal rate of force development (RFD) increased from 29,724 $N \cdot s^{-1}$ in the DMVJ to 34,171 $N \cdot s^{-1}$ in the DQVJ, reflecting a 4,447 $N \cdot s^{-1}$ (approximately 15%) steeper slope of impact force over time. A greater RFD is unsafe because it shortens the timeframe for muscular shock absorption and puts more stress on the knee's ligaments (Padua et al., 2015). Athletes who generate force quickly are prone to land with stiffness and inadequate energy dissipation, which are both related with higher risk of ACL injury. These findings are consistent with Peng et al. (2011), who found that tasks demanding quick takeoff, such as the DQVJ, frequently had higher force peaks and less controlled landings. The combination of higher peak vGRF and quicker force application puts athletes at increased risk, especially during unexpected or reactive landings.

Examining the neuromuscular pre-activation levels in the semitendinosus (ST) and vastus lateralis (VL), muscles that plays opposite roles in anterior-posterior knee stability, the DQVJ was associated with significantly higher pre-activation in both muscles: ST increased by 11 %MVC_peak (from 26.25% to 37.20%), while VL increased by 5 %MVC_peak (from 14.50% to 19.70%) in the 10 ms prior to IC. Increased ST pre-activation is generally considered protective because the hamstrings act to resist anterior tibial translation and decelerate knee extension forces generated by the quadriceps (Zebis et al., 2009). As such, higher ST activity may help stabilize the knee, particularly in the presence of rapid landing forces. In contrast, increased VL pre-activation may signal continued quadriceps dominance, a known neuromuscular risk factor for ACL injury, especially in female athletes (Hewett et al., 2010). High quadriceps activity immediately before landing can increase anterior tibial shear and increase ACL strain, especially if not sufficiently counteracted by the hamstrings. Zebis et al. (2009) previously found that athletes who later sustained ACL injuries exhibited lower semitendinosus activation (~21% of MVC_peak) and higher vastus lateralis activation (~69% of MVC_peak), suggesting that a disproportionate increase in quadriceps pre-activation, even in the presence of hamstring activity, could compromise joint stability. This suggests that the increased VL pre-activation may be more indicative of ACL injury risk, as elevated quadriceps activity is linked to injurious loading patterns in female athletes. In contrast, the rise in ST activation in our study, while not directly associated with injury risk, may reflect a protective or preparatory response in our healthy population. Since all participants were injury free, higher hamstring activation could indicate effective neuromuscular readiness rather than risk. However, this pattern may still reduce the hamstrings' stabilizing role if VL activity is disproportionately high. As our study did not assess co-contraction ratios, it remains unclear whether ST activation sufficiently offset the rise in VL. Future research should examine VL:ST or Q:H activation ratios to clarify these implications.

These study findings provide strong evidence that the DQVJ may be more sensitive to identify kinematics, kinetic, sand neuromuscular variables that are associated with ACL injury compared to the DMVJ. The DQVJ elicited stiffer sagittal-plane landings, more severe and faster frontal-plane knee motion, and higher magnitudes and rates of impact force. The DQVJ landing pattern mirrors the "*ligament-dominant*" mechanism described in earlier research and aligns with video analyses of actual ACL ruptures, where rapid valgus collapse and high loading rates are present within the first 50 milliseconds of foot strike (Koga et al., 2010; Hewett et al., 2010). The consistency of these findings across kinematic, kinetic, and neuromuscular domains supports the notion that the DQVJ is a valuable screening tool capable of amplifying ACL risk markers that might remain subtle during other tasks.

These findings carry several practical implications for coaches, clinicians, and researchers. From a screening perspective, incorporating a DQVJ task into preseason assessments may help identify athletes who exhibit poor landing mechanics under time pressure. Specifically, athletes who land with limited knee flexion, elevated valgus velocity, or high vGRF may be at increased risk and could benefit from targeted neuromuscular interventions. Exercises focused on increasing hamstring strength, improving frontal-plane control, and enhancing proprioception may help mitigate the high-risk mechanics observed in this task (Myer et al., 2009; Sugimoto et al., 2015). Importantly, using the DQVJ in both assessment and intervention contexts may improve the ecological validity of ACL injury prevention efforts, making them more transferable to actual sport scenarios.

While the findings of this study provide meaningful insight into ACL injury risk, several limitations should be acknowledged. The participant group consisted exclusively of healthy female NCAA Division II athletes regularly engaged in strength and conditioning training, which may limit the generalizability of these findings to populations such as untrained individuals, previously injured athletes, males, or elite-level competitors. The controlled laboratory setting, though essential for consistency, does not fully capture the complex and unpredictable nature of real-game environments. For example, fatigue, which often arises in late game scenarios and is known to negatively affect neuromuscular control, was not introduced during testing and may influence landing mechanics differently under more realistic conditions. Furthermore, trunk and hip kinematics, which play a key role in the control of frontal plane knee motion, were not included in this analysis and should be incorporated in future studies. Finally, the drop height used in this study (31 cm) was based on prior literature for consistency, but it is possible that varying the height could influence the expression of risk factors differently. Testing a range of drop heights may help determine whether certain tasks elicit risky mechanics only beyond specific thresholds or under constraints.

In conclusion, the fast reactive tasks like the DQVJ are more sensitive to detecting risky movement patterns associated with ACL injury and may be more appropriate for screening and training purposes than maximal height focused tasks. Integrating this type of landing/jumping into both assessment protocols and injury prevention programs could offer a more realistic and functionally relevant approach to identifying and mitigating ACL injury risk in athletic populations.

CONCLUSION

This study demonstrated that the DQVJ is more sensitive than the DMVJ in identifying movement patterns associated with increased ACL injury risk factors in collegiate female athletes. The DQVJ consistently revealed stiffer landings, greater frontal-plane knee motion, and altered muscle activation strategies, which are commonly linked to elevated ACL injury risk. These findings may be explained by the DQVJ's closer resemblance to sport specific, reactive scenarios where injuries frequently occur. The DQVJ highlights ACL injury risk factors that might be missed during slower, more controlled assessments like the DMVJ by better simulating the speed and intensity of real-game movements. The DQVJ may offer a practical and functionally relevant screening method that may help coaches, athletic trainers, and clinicians more accurately identify at risk athletes and design targeted training programs to reduce injury risk in sport specific contexts.

AUTHOR CONTRIBUTIONS

Maya Caon, MSc: Conceived and developed the research project under the supervision of Dr. Tal Amasay. Led all aspects of the study, including literature review, participant recruitment, data collection, data processing, statistical analysis, and manuscript writing. Managed all revisions and integrated feedback from committee members to finalize the manuscript. Dr. Tal Amasay: Served as thesis chair and principal supervisor. Co-developed the research project, guided methodological design, and oversaw each stage of the study. Provided critical input during data analysis and manuscript development, offering feedback on all versions of the document. Dr. David Suprak: Provided academic oversight during study design and data interpretation. Contributed extensively to the refinement of the manuscript, especially regarding structure, clarity, and scientific rigor. Participated in the thesis defence and final approval of the study. Dr. Claire Egret: Supported the design of the research and data analysis. Reviewed manuscript drafts and provided feedback, particularly on the discussion and interpretation of findings. Dr. Nathaniel Boiangin: Participated in the research design and assisted with data analysis. Contributed editorial feedback on the manuscript, particularly improving the discussion section, grammar, and formatting.

SUPPORTING AGENCIES

No funding agencies were reported by the authors. The project was conducted as part of the requirements for the completion of the master's degree in Kinesiology and Human Performance at Barry University.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

REFERENCES

Agel, J., Rockwood, T., & Klossner, D. (2016). Collegiate ACL Injury Rates Across 15 Sports: National Collegiate Athletic Association Injury Surveillance System Data Update (2004-2005 Through 2012-2013). Clinical Journal of Sport Medicine, 26(6), 518. https://doi.org/10.1097/JSM.0000000000000290

Dauty, M., Crenn, V., Louguet, B., Grondin, J., Menu, P., & Fouasson-Chailloux, A. (2022). Anatomical and Neuromuscular Factors Associated to Non-Contact Anterior Cruciate Ligament Injury. Journal of Clinical Medicine, 11(5), Article 5. https://doi.org/10.3390/jcm11051402

Dewig, D. R., Boltz, A. J., Moffit, R. E., Rao, N., Collins, C. L., & Chandran, A. (2024). Epidemiology of Anterior Cruciate Ligament Tears in National Collegiate Athletic Association Athletes: 2014/2015-2018/2019. Medicine & Science in Sports & Exercise, 56(1), 29. https://doi.org/10.1249/MSS.0000000000003281

Ford, K. R., Myer, G. D., & Hewett, T. E. (2003). Valgus Knee Motion during Landing in High School Female and Male Basketball Players: Medicine & Science in Sports & Exercise, 35(10), 1745-1750. https://doi.org/10.1249/01.MSS.0000089346.85744.D9

Freedman, K. B., Glasgow, M. T., Glasgow, S. G., & Bernstein, J. (1998). Anterior cruciate ligament injury and reconstruction among university students. Clinical Orthopaedics and Related Research, 356, 208-212. https://doi.org/10.1097/00003086-199811000-00028

Herzog, M. M., Marshall, S. W., Lund, J. L., Pate, V., & Spang, J. T. (2017). Cost of Outpatient Arthroscopic Anterior Cruciate Ligament Reconstruction Among Commercially Insured Patients in the United

States, 2005-2013. Orthopaedic Journal of Sports Medicine, 5(1), 2325967116684776. https://doi.org/10.1177/2325967116684776

Hewett, T. E., Ford, K. R., Hoogenboom, B. J., & Myer, G. D. (2010). Understanding and preventing acl injuries: current biomechanical and epidemiologic considerations - update 2010. North American Journal of Sports Physical Therapy : NAJSPT, 5(4), 234-251.

Hewett, T. E., Myer, G. D., & Ford, K. R. (2006). Anterior cruciate ligament injuries in female athletes: Part 1, mechanisms and risk factors. The American Journal of Sports Medicine, 34(2), 299-311. https://doi.org/10.1177/0363546505284183

Hewett, T. E., Myer, G. D., Ford, K. R., Heidt, R. S., Colosimo, A. J., McLean, S. G., van den Bogert, A. J., Paterno, M. V., & Succop, P. (2005). Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes: A prospective study. The American Journal of Sports Medicine, 33(4), 492-501. https://doi.org/10.1177/0363546504269591

Kiapour, A. M., Quatman, C. E., Goel, V. K., Wordeman, S. C., Hewett, T. E., & Demetropoulos, C. K. (2014). Timing Sequence of Multi-Planar Knee Kinematics Revealed by Physiologic Cadaveric Simulation of Landing: Implications for ACL Injury Mechanism. Clinical Biomechanics (Bristol, Avon), 29(1), 75-82. https://doi.org/10.1016/j.clinbiomech.2013.10.017

Koga, H., Nakamae, A., Shima, Y., Iwasa, J., Myklebust, G., Engebretsen, L., Bahr, R., & Krosshaug, T. (2010). Mechanisms for noncontact anterior cruciate ligament injuries: Knee joint kinematics in 10 injury situations from female team handball and basketball. The American Journal of Sports Medicine, 38(11), 2218-2225. https://doi.org/10.1177/0363546510373570

Krosshaug, T., Nakamae, A., Boden, B. P., Engebretsen, L., Smith, G., Slauterbeck, J. R., Hewett, T. E., & Bahr, R. (2007). Mechanisms of anterior cruciate ligament injury in basketball: Video analysis of 39 cases. The American Journal of Sports Medicine, 35(3), 359-367. https://doi.org/10.1177/0363546506293899

Murphy, D. F., Connolly, D. a. J., & Beynnon, B. D. (2003). Risk factors for lower extremity injury: A review of the literature. British Journal of Sports Medicine, 37(1), 13-29. https://doi.org/10.1136/bjsm.37.1.13

Myer, G. D., Ford, K. R., Barber Foss, K. D., Liu, C., Nick, T. G., & Hewett, T. E. (2009). The relationship of hamstrings and quadriceps strength to anterior cruciate ligament injury in female athletes. Clinical Journal of Sport Medicine: Official Journal of the Canadian Academy of Sport Medicine, 19(1), 3-8. https://doi.org/10.1097/JSM.0b013e318190bddb

NCAA. (2012, November 28). Obstacle Course. NCAA.Org. Retrieved from [Accessed 2025, 15 October]: https://www.ncaa.org/news/2012/11/28/obstacle-course.aspx

Pfeifer, C. E., Beattie, P. F., Sacko, R. S., & Hand, A. (2018). Risk factors associated with non-contact anterior cruciate ligament injury: a systematic review. International Journal of Sports Physical Therapy, 13(4), 575-587. https://doi.org/10.26603/ijspt20180575

Putukian, M. (2016). The psychological response to injury in student athletes: A narrative review with a focus on mental health. British Journal of Sports Medicine, 50(3), 145-148. https://doi.org/10.1136/bjsports-2015-095586

Schmorantz, D., Amasay, T., Boiangin, N., & Egret, C. (2024). Mechanical differences between three block jump approaches in NCAA DII college volleyball players. Scientific Journal of Sport and Performance, 3(2), Article 2. https://doi.org/10.55860/KIUU6271

Shinde, T., Saito, A., Okada, K., Wakasa, M., Kimoto, M., Kamada, T., Shibata, K., Okura, K., Sato, H., & Takahashi, Y. (2022). Influence of lower extremity rotation on knee kinematics in single-leg landing. Physical Therapy in Sport, 58, 87-92. https://doi.org/10.1016/j.ptsp.2022.10.002

Sugimoto, D., Myer, G. D., Foss, K. D. B., & Hewett, T. E. (2015). Specific exercise effects of preventive neuromuscular training intervention on anterior cruciate ligament injury risk reduction in young

females: Meta-analysis and subgroup analysis. British Journal of Sports Medicine, 49(5), 282-289. https://doi.org/10.1136/bjsports-2014-093461
Yu, B., Lin, C.-F., & Garrett, W. E. (2006). Lower extremity biomechanics during the landing of a stop-jump task. Clinical Biomechanics, 21(3), 297-305. https://doi.org/10.1016/j.clinbiomech.2005.11.003
Zebis, M. K., Andersen, L. L., Bencke, J., Kjaer, M., & Aagaard, P. (2009). Identification of athletes at future risk of anterior cruciate ligament ruptures by neuromuscular screening. The American Journal of Sports Medicine, 37(10), 1967-1973. https://doi.org/10.1177/0363546509335000
Zebis, M. K., Bencke, J., Andersen, L. L., Døssing, S., Alkjær, T., Magnusson, S. P., Kjær, M., & Aagaard, P. (2008). The Effects of Neuromuscular Training on Knee Joint Motor Control During Sidecutting in Female Elite Soccer and Handball Players. Clinical Journal of Sport Medicine, 18(4), 329. https://doi.org/10.1097/JSM.0b013e31817f3e35