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# Ankle Stability and Dynamic Single-Leg Balance in Collegiate Jumping Athletes versus Non-Athletes

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**Abstract:** The purpose of this study was to compare ankle stability and dynamic single-leg balance between jumping athletes and non-athletes, and to examine the correlation between ankle stability and dynamic single-leg balance. Thirty-eight jumping athletes and thirty-seven non-athletes participated in this study. The Cumberland Ankle Instability Tool (CAIT) was used to assess ankle stability. The Y-Balance Test (YBT) was used to examine single-leg balance in the anterior (AN), posteromedial (PM), and posterolateral (PL) directions. The results show that 42.11% of jumping athletes and 21.62% of non-athletes exhibited chronic ankle instability (CAI) in their examined leg. In addition, jumping athletes exhibited significantly worse ankle stability than non-athletes ($p = 0.038$). The two groups showed no significant difference in the YBT scores in all directions ($p = 0.113$ AN, 0.567 PM, 0.542 PL). Very low correlations were found between the CAIT and the YBT scores in all directions ($r < 0.107$). In conclusion, single-leg jumping athletes experienced a higher prevalence of CAI and significantly worse ankle stability than non-athletes. However, the results of the YBT did not correlate strongly with the CAIT scores, suggesting an inability to predict dynamic single-leg balance deficits based on perceived ankle stability alone in this population.

**Keywords:** balance; ankle stability; jumping athletes; proprioception

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## 1. Introduction

It is estimated that more than 120,000 sports injuries occur among collegiate track and field athletes every year, and jumping athletes account for 20,910 of those injuries [1,2]. A lateral ankle sprain is the most common injury among NCAA jumping athletes [3]. Excessive repetitive loading can cause greater strain for a given load in ligaments and joint capsules, leading to less effective joint stabilization. Studies have shown that during the take-off phase of jumping, peak ground reaction forces (GRFs) experienced by the take-off leg can reach up to 5933 N, which is about eight times the athlete's body weight and two times the GRF experienced by a sprinter of the same average body mass [4,5]. With single-leg jumping being such a dynamic movement, it is difficult to achieve the same foot strike for every take-off. The high GRFs from jumping applied to an inverted foot could put a strain on the lateral ankle ligaments. With repetitive exposure to excessive stress, a jumping athlete can become more susceptible to lateral ankle sprains and recurrent injuries. In one observational study of 117 injuries sustained by jumping athletes, nearly 60% of injuries occurred in the take-off leg, with the lateral ankle being the most common site of injury [6].

In track and field, a jumping event has two similar components in its execution: the approach and the take-off. While a triple jump cycles through both legs in its overall take-off, a high jump, long jump, and pole vault utilize only one leg in their take-off phase. The athletes participating in these events use the same leg, their "take-off leg", every time they jump. This take-off leg can be different from the dominant leg. Van Melick et al. (2017)

reported that only 52 percent of men and 70 percent of women used their dominant leg as the take-off leg during single-leg jumping events [7]. In pole vaulting, the take-off leg is determined entirely by upper extremity dominance and how an athlete grips the pole. Right-handed athletes will often take off with their left leg and vice versa.

Jumping athletes are at a high risk of developing chronic ankle instability (CAI) due to repetitive loading sustained by the take-off leg and the high prevalence of lateral ankle sprains. CAI is identified as a condition of lateral ankle pain, recurrent injury, and instability characterized by having a "giving way" feeling at the ankle joint lasting more than 12 months [8,9]. This chronic instability is due to compromised connective tissue and sensorimotor impairments [9]. CAI may have a profound negative impact on balance performance and can develop within 6–12 months after the initial lateral ankle sprain [8]. It was reported that athletes with CAI exhibited a significant decrease in dynamic balance performance compared to athletes without CAI [10]. In addition to hampered mechanical stabilizers (ligaments and the joint capsule), ankle proprioception could be compromised in individuals with CAI. It was reported that damaged mechanoreceptors in lateral ankle ligaments or decreased neuromuscular control could contribute to proprioception deficits [10]. The literature also suggests that centrally mediated processes, such as spinal-level sensorimotor reflexes and supra-spinal corticomotor functions, could also be compromised in individuals with CAI [9].

Dynamic single-leg balance is an important aspect of jumping mechanics. As an athlete approaches the take-off phase of their jump, proper foot placement can increase peak GRF and properly direct force application to improve sports performance [4]. Becoming off balance at take-off can compromise an athlete's form, place the take-off leg in a more precarious position, and increase the risk of sports-related injuries [8]. The Y-Balance Test (YBT) is commonly used for single-leg dynamic balance assessments. The results of the YBT could be a reliable indicator of CAI and potential lower extremity injuries [11]. Recognizing the signs of ankle instability and applying proper interventions in its early phases are important factors in reducing incidents of CAI and preventing further injuries [11].

The first goal of this study was to determine whether the take-off leg of jumping athletes exhibited ankle instability and compromised dynamic single-leg balance compared to non-athletes. The second goal was to examine if individuals with more ankle instability would also have worse dynamic single-leg balance. We hypothesized that the repetitive loads placed on the ankle in jumping athletes would negatively affect their ankle stability and dynamic single-leg balance due to increased laxity of the ankle ligaments and joint capsule. We also hypothesized that individuals with worse ankle stability would exhibit worse single-leg balance control because the ankle joint is part of the lower extremity kinematic chain. Not having proper mechanical support and proprioceptive feedback from the ankle joint could negatively impact the overall balance performance.

## 2. Materials and Methods

### *2.1. Participants*

Seventy-five volunteers (38 jumping athletes and 37 non-athletes; aged 18–30 years) participated in the study. Inclusion criteria included (1) having no pain or discomfort in their examined leg during single-leg stance and (2) having lower extremity range of motions within functional limits. Exclusion criteria included (1) having current ankle, knee, or hip injuries that would prohibit them from performing single-leg stance, (2) having undergone orthopedic surgery on the examined lower extremity within the past 6 months, (3) having to wear a physician-prescribed ankle brace, and (4) having a Body Mass Index of 30 or higher. To be considered a jumping athlete for the present study, the athlete needed to perform single-leg jumps consistently off the same leg in their respective events such as pole vaulting, the high jump, the long jump, the heptathlon, and the decathlon. The college-aged non-athletes all met the American College of Sports Medicine's weekly activity recommendations (engage in moderate-intensity aerobic physical activity of at least

150 min per week) [12]. All participants signed the informed consent form approved by the Institutional Review Board of the local university.

### 2.2. Measures

The Cumberland Ankle Instability Tool (CAIT) was used to examine perceived ankle instability. It is a self-report questionnaire of 9 questions about perceived stability, pain, and injury prevention ability. The CAIT has a Youden index of 68.1 and a test-retest reliability of 0.96 [13]. Scores can range from 0 (worst) to 30 (best), and a score of 25 or less indicates the presence of chronic ankle instability [9]. Dynamic single-leg balance control is an important factor in lower extremity injury prediction, prevention, and rehabilitation processes [14]. The YBT is a reliable tool for dynamic balance examination [15–17]. The YBT kit consists of a standing platform and 3 lower extremity reaching indicators in the anterior (AN), posteromedial (PM), and posterolateral (PL) directions [18]. The anterior indicator is positioned 135 degrees from the posterior indicators, which are positioned 90 degrees from each other. Each indicator is marked in 5 mm increments for length measurement. The YBT has an inter-rater reliability of 0.88 (anterior), 0.87 (posteromedial), and 0.88 (posterolateral), and an intra-rater reliability of 0.88 (anterior), 0.88 (posteromedial), and 0.90 (posterolateral) [14].

### 2.3. Procedures

After obtaining consent, examiners performed a screening test to see if the participants met the inclusion/exclusion criteria. The screening test included a squat test for the lower extremities to evaluate the hip, knee, and ankle range of motion. Participants were asked to squat down without shoes until their thighs were parallel to the floor. After passing the screening test (achieving the squat position without lifting the heels off the ground), the CAIT questionnaire was given to each participant to determine if chronic ankle stability was present in their take-off leg. For non-athletes, the take-off leg was established by performing 3 single-leg jumping trials with a 10-foot running start. Their self-selected leg for most trials was designated as their take-off leg. For jumping athletes, each participant was asked which leg they jumped off of during their respective collegiate track events to determine their take-off leg. The take-off leg was used as the supporting leg during the YBT.

Before the YBT, participants were placed in a supine position. The researchers measured the take-off leg length from the anterior superior iliac spine to the medial malleolus with a cloth tape measure [19]. For the YBT, each participant stood on the center block of the YBT kit with their examined leg. They were then asked to reach out and push the indicator in each direction (anterior, posteromedial, and posterolateral) with their free leg while balancing on their supporting leg and keeping their hands on their hips (Figure 1). Participants had 4 practice trials and 3 official trials in each direction [11,20]. The trial was discarded and repeated if the participant failed to maintain a unilateral stance on the platform, maintain contact with the reach indicator, or return the reaching foot to the starting position under control. The maximum reach scores of the 3 trials were normalized to each participant's leg length (AN, PM, PL), and the composite normalized value (CN) of the 3 directions was also calculated for data analyses [21].


(**A**) (**B**) (**C**)

**Figure 1.** Testing positions/directions of the Y-Balance Test. (**A**) Anterior direction; (**B**) posterior medial direction; (**C**) posterior lateral direction.

### *2.4. Data Analysis*

Statistical analyses were performed using IBM SPSS version 26 (IBM Corp., Armonk, NY, USA). An independent-sample *t*-test was conducted to compare the CAIT scores, the normalized scores for all 3 directions of the YBT, and the composite scores of the YBT between the athlete and non-athlete groups. A Pearson Correlation coefficient analysis was conducted to examine the correlation between the CAIT scores and dynamic single-leg balance. Cohen's d effect size was calculated to determine the size of the significance between groups. When comparing the different jumping disciplines in the athlete group, a one-way ANOVA was used to determine any significant difference between groups. Further, a post hoc test was used to determine a significant difference between specific athlete groups. The significance (*p*-value) was set at 0.05 for all comparisons.

## **3. Results**

Descriptive statistics for the CAIT and the YBT are shown in Tables 1 and 2. This study found that 42.11% of jumping athletes and 21.62% of non-athletes exhibited CAI in their take-off leg (Table 1). In addition, jumping athletes demonstrated significantly worse CAIT scores than non-jumping athletes [t (73) = 2.115, $p = 0.038$; Figure 2]. A Cohen's d equation for the *t*-test found an effect size of d = 0.49 (very close to a medium effect) between groups comparing CAIT scores. The two groups had no significant difference in the YBT scores in all directions [t (73) = −1.604, $p = 0.113$ AN; t (73) = −1.608, $p = 0.567$ PM; t (73) = 0.855, $p = 0.542$ PL; t (73) = 0.827, $p = 0.311$ CN; Table 1, Figure 3). A Cohen's d equation for the *t*-test found an effect size of d = 0.371 AN (small to medium effect size), 0.133 PM (very small effect size), 0.142 PL (very small effect size), 0.236 CN (small to medium effect size) between groups. In addition, only very low correlations were found between the CAIT and the YBT scores in all directions (r = 0.052 AN, −0.067 PM, −0.107 PL, −0.046 CN).

**Table 1.** Cumberland Ankle Instability Tool (CAIT) scores for non-athletes and athletes. CAI: chronic ankle instability.

| Non-Athletes | | | | | |
|---|---|---|---|---|---|
| | **# of Non-Athletes** | **Average CAIT Score** | **Std. Deviation** | **# of CAI** | **% of CAI** |
| | 37 | 26.95 | 3.34 | 8 | 21.62 |
| Athletes | | | | | |
| **Sport** | **# of Athletes** | **Average CAIT Score** | **Std. Deviation** | **# of CAI** | **% of CAI** |
| Athlete Group | 38 | 25.18 | 3.85 | 16 | 42.11 |
| Heptathlon (High Jump, Long Jump) | 7 | 23.57 | 3.95 | 4 | 57.14 |
| Decathlon (Pole Vault, Long Jump, High Jump) | 8 | 25.50 | 4.14 | 2 | 25 |
| Pole Vault | 9 | 26.22 | 4.09 | 3 | 33.33 |
| High Jump | 7 | 25.43 | 2.88 | 4 | 57.14 |
| Long Jump | 7 | 24.86 | 4.49 | 3 | 42.86 |

**Table 2.** Average Y-Balance Test normalized scores in various groups.

| | Anterior Normalized | Posteromedial Normalized | Posterolateral Normalized | Composite Normalized |
|---|---|---|---|---|
| Non-Athlete Group | 73.50 | 114.27 | 111.24 | 99.67 |
| Athlete Group | 76.79 | 115.45 | 106.12 | 97.37 |
| Heptathalon | 74.39 | 111.59 | 111.40 | 101.74 |
| Decathalon | 77.49 | 116.33 | 110.22 | 97.94 |
| High Jump | 73.24 | 110.35 | 113.44 | 100.78 |
| Pole Vault | 73.03 | 115.88 | 121.57 | 110.40 |
| Long Jump | 86.79 | 122.83 | 112.57 | 101.60 |

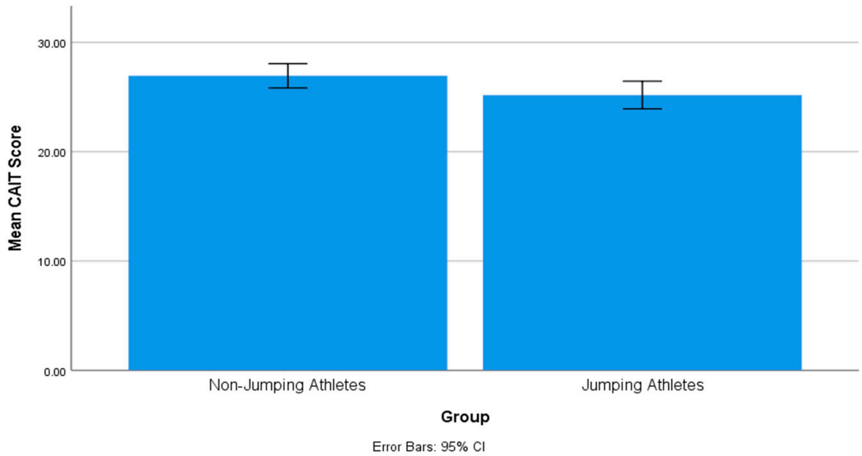


**Figure 2.** Mean CAIT scores in single-leg jumping athletes vs. non-athlete subjects. The error bar denotes 1 SD.

The YBT results among different athletic groups were further analyzed. The results of the ANOVA show a significant difference among athletes in the anterior direction (F = 3.211, $p = 0.025$) and composite score (F = 2.933, $p = 0.033$). The post hoc test shows long jumpers performing better than high jumpers ($p = 0.045$) and pole vaulters ($p = 0.026$) in the anterior direction. In addition, long jumpers outscored heptathletes ($p = 0.034$) and high jumpers ($p = 0.047$) in the composite normalized scores. No significant difference was found in the CAIT scores between the athletic groups (F = 0.476, $p = 0.753$).

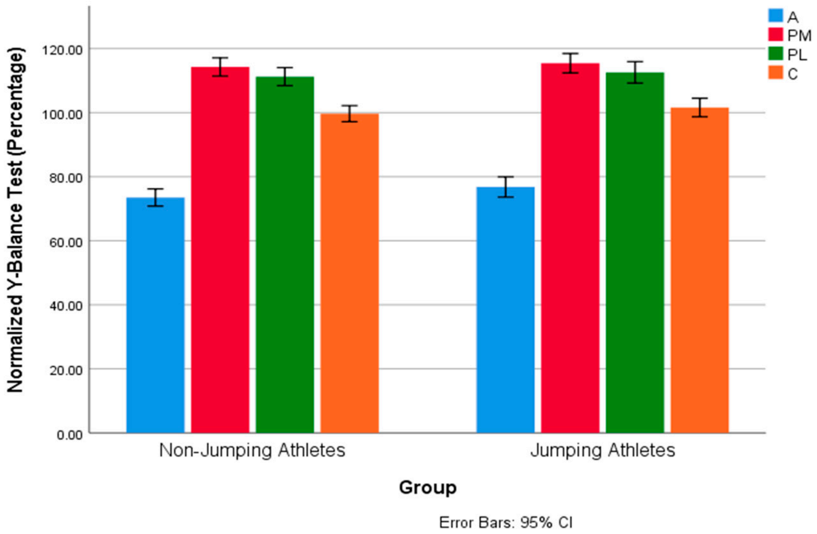


**Figure 3.** Y-Balance Test scores. A: anterior direction; PM: posterior medial direction; PL: posterior lateral direction; C: composite. The error bar denotes 1 SD.

## 4. Discussion

The CAIT scores obtained from participants revealed that jumping athletes exhibited a greater prevalence of CAI and significantly worse ankle stability (lower CAIT scores) compared to non-athletes. These results agree with our hypotheses and could be due to the repetitive loading and prior injuries sustained by a collegiate jumper's take-off leg. There is limited research evaluating the prevalence of CAI in single-leg jumping athletes and the factors that may contribute to this finding. The current literature indicates NCAA single-leg jumping athletes often experience ankle sprains, which may contribute to the high prevalence of CAI [3]. In addition to compromised mechanical stability, lax ligaments and joint capsules could also compromise proprioception of the ankle joint. Because local mechanoreceptors are sensitive to stretch, proprioceptive feedback would be compromised in ankle joints with lax ligaments and joint capsules. As a result, jumping athletes might experience compromised proprioceptive information and therefore feel less stable at their ankle joint (having a lower CAIT score) [10,22–25].

There was no significant difference in dynamic single-leg balance performance between jumping athletes and non-athletes. This result contradicts our hypothesis that athletes would have decreased dynamic single-leg balance due to ankle ligament laxity from repetitive stresses and recurrent injuries. Research suggests that individuals with CAI often experience episodes of giving way due to compromised proprioceptive inputs from lax ankle ligaments [22,23]. One possible explanation for the lack of single-leg balance performance difference between the groups is that jumping athletes might have enhanced motor control of the lower extremities through years of training. Therefore, they might be able to cope with the ankle deficit by heightening the senses from other joints or using compensatory strategies. In addition, jumping athletes might have greater self-motivation or be more competitive during testing than non-athletes. As a result, these psychological factors could enhance their performance and dampen the negative impact of ankle instability.

Another aim of this study was to examine if individuals with worse ankle stability would exhibit worse balance control. The correlation analysis shows a small correlation between the two outcome measures. This result contradicts the hypothesis of the present study. It suggests the integrity of the ankle joint may not play a significant role in overall dynamic balance control. Although the ankle joint is part of the lower extremity kinematic chain, one possible explanation of this finding is that the hip joint could have played a more important role in single-leg balance control. The muscles around the hip joint are more powerful than the muscles around the ankle joint, and the range of motion of the hip joint is much greater than the range of motion of the ankle joint. Although Tao et al.

(2020) found minimal relationships between static balance control and isometric ankle and hip muscle strength using a handheld dynamometer [26], future studies to examine the role of the ankle joint versus the hip joint in dynamic single-leg balance control will be beneficial. In addition, implementing functional balance testing (such as the side-hop test) that better stresses ankle stabilizers may be more effective in differentiating individuals with or without ankle instability.

When comparing different jumping events, long jumpers performed better on the YBT than high jumpers, pole vaulters, and heptathletes. This could be due to the overall nature of the take-off approach between jumping events. The hip joint is utilized more vigorously in maximal effort horizontal jumping mechanics when compared to maximal vertical jumping [24]. This could indicate less peak stress through the ankle joint in horizontal jumping and help the long jumpers compensate for ankle instability with hip strategies for balance recovery. Long jumpers also had a more horizontal take-off force than high jumpers and pole vaulters [25]. Therefore, long jumpers experienced more horizontal body mass displacement in the anterior direction and a longer time in ankle dorsiflexion compared to the high jump and pole vault athletes [24]. This could help explain the improved performance of long jumpers in the anterior direction of the YBT, as they might be more accustomed to operating outside of their base of support in this specific direction.

Clinicians and coaches should be aware of potential ankle stability deficits in jumping athletes. The CAIT is a valid and reliable tool for screening ankle instability. For athletes with ankle instability, clinicians may consider implementing strength, proprioception, and balance training to enhance performance and/or reduce injuries. In addition, one should also consider the specificity of the athletes and movements when choosing balance tests or treatment protocols. Although the YBT is known for testing dynamic single-leg balance for the general population, it may not be specific enough for jumping athletes. Moreover, the take-off leg of different jumping athletes may experience forces with different directions or magnitude, therefore exhibiting different balance control deficits toward different directions. It would be beneficial for clinicians and coaches to understand the biomechanics of the sports to construct individualized prevention strategies for ankle injuries.

## 5. Limitations

The primary limitation of this study was using the YBT as the only assessment tool to measure dynamic balance in jumping athletes without addressing sport-specific factors. The YBT is a commonly used test for assessing dynamic single-leg balance and can be implemented conveniently for a large number of participants and in various locations. However, it does not simulate the sport-specific nature and movement of track and field collegiate jumping athletes. It may be beneficial to include other field tests such as the side-hop test or the triple hop test in future studies. Another limitation of the study is the small sample size. A larger sample size could increase the effect size of the study and have stronger power to compare the differences between sports. In addition, the fitness level of non-athletes could be better controlled in future studies. Although the non-athletes in the present study met the American College of Sports Medicine's weekly exercise recommendation, their strength and endurance levels were unknown in comparison to jumping athletes. In addition, considering that muscles that control the hip joint may play an important role in balance control, it will be beneficial for future studies to examine the electromyography of hip muscles during dynamic single-leg balance tests. Lastly, it will be beneficial to compare the ankle range of motion and the center of pressure movement with stabilometry during dynamic single-leg balance between jumping athletes and non-athletes [27].

## 6. Conclusions

Single-leg jumping athletes experienced a higher prevalence of CAI and significantly worse ankle stability than non-athletes. However, the two groups exhibited no significant difference in all three directions of the YBT. The results of the YBT did not correlate well with the CAIT scores, indicating an inability to predict dynamic balance deficits based on the CAIT scores alone in this population. Further studies should be performed to evaluate the effects of CAI on single-leg jumping performance. Clinicians and coaches should be prepared to educate and treat athletes with CAI on the prevention of further ankle sprains and proper rehabilitation.

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