The Influence of Inter-limb Asymmetry and Force Production on Vertical Jump Performance Across Athlete Population

Pablo Tadeo Ríos-Gallardo, PhD(c).[1], Luis Enrique Carranza-García, PhD.[1], Luis Carlos Esquivel-Mendoza, MSc.[1], Germán Hernández-Cruz, PhD.[1], Matthew P. Gonzalez, PhD.[2], Miguel Narváez, PhD.,[3] Samuel Montalvo PhD.[4]

[1]School of Sport Organization, Autonomous University of Nuevo León, México., [2]Department of Kinesiology, University of Texas at San Antonio, Texas, USA., [3]School of Health Sciences and Human Movement, Colorado State University Pueblo, USA [4]Wu Tsai Performance Alliance, Division of Cardiovascular Medicine, Stanford University, California, USA.

Background

- Inter-limb asymmetry can impair jump performance and increase injury risk, but its effects vary across sports and remain insufficiently understood.
- Sport-specific adaptations (e.g., in soccer, volleyball, basketball) may moderate how asymmetry influences vertical jump height.

Objectives/Aims

- Examine how takeoff force asymmetry relates to countermovement jump performance across different athlete populations.
- Determine whether sport-specific training adaptations modify the impact of asymmetry on jump height.

Methods

- **Design:** Repeated-measures observational study with two testing sessions separated by 7–10 days to assess test-retest reliability and relationships between takeoff force asymmetry and jump height.
- **Participants:** 80 male athletes stratified into four groups (recreational, basketball, soccer, volleyball), ranging from moderate to elite international levels.
- **Procedures:** Each athlete performed three countermovement jumps per session on a dual force plate system after standardized warm-up and pre-testing controls (*Figure 1*).
- **Measurements:** Vertical ground reaction forces (1,000 Hz) were used to calculate jump height (impulse-momentum method), peak force, and takeoff force asymmetry (% difference between limbs).
- **Statistical Analysis:** Linear mixed-effects models tested the effects of takeoff force asymmetry, peak force, and body mass on jump height, with *group × asymmetry* interaction terms. Test-retest reliability assessed via ICC, SEM, CV, and Cohen's Kappa. Variance explained by the models reported as marginal R^2 (e.g., the full LMM marginal $R^2 = 0.465$).
- **Software:** Data processed and analyzed in R (v4.5.3), with statistical significance set at an alpha level of 0.05.

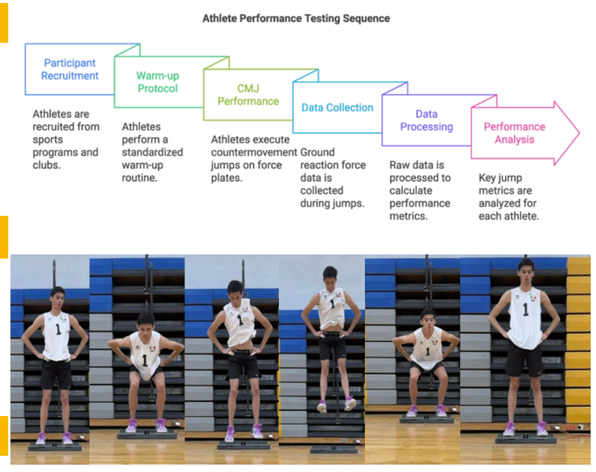

Figure 1. Overview of testing protocol and CMJ execution phases. Upper panel: procedural flow diagram. Lower panel: key movement phases during CMJ assessment.

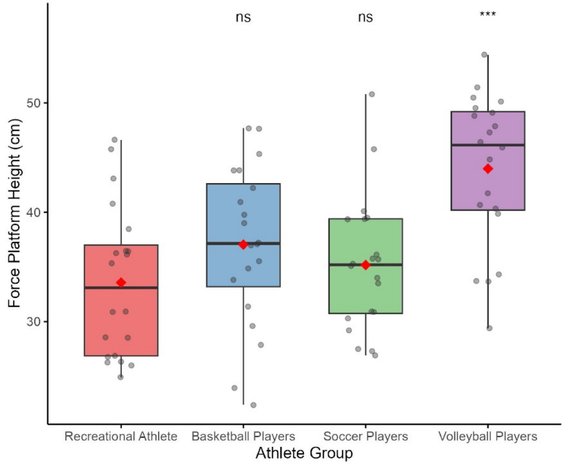

Figure 2. CMJ height by group (Test session). Boxes show IQR and median; red diamonds = means. Brackets indicate significant differences vs. Recreational Athletes ($p < 0.05$ to $^{**}p < 0.001$).

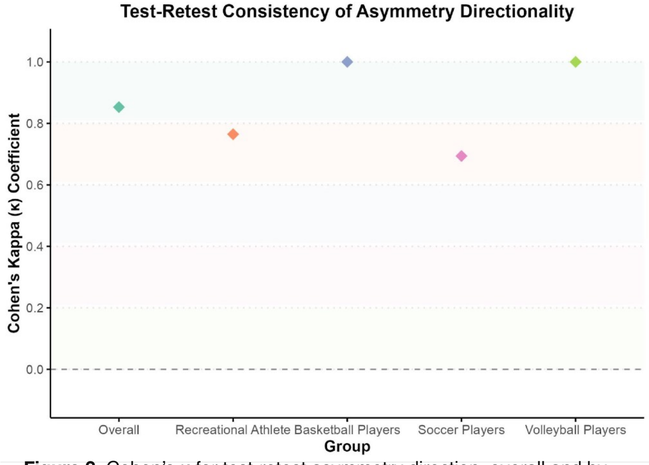

Figure 3. Cohen's κ for test-retest asymmetry direction, overall and by group. Shading reflects Landis & Koch agreement levels.

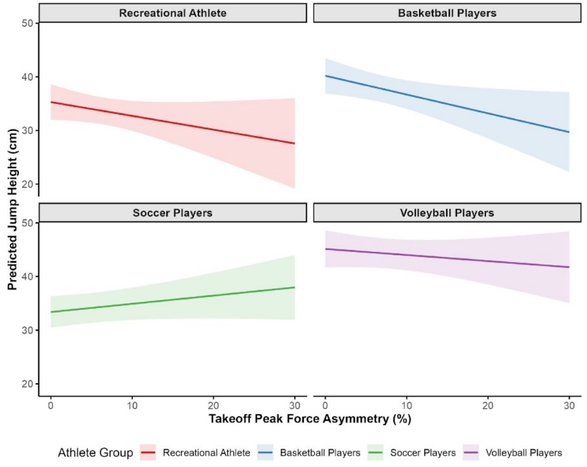

Figure 4. Predicted jump height by asymmetry (%) from LMM, shown by group. Lines = model predictions; shading = 95% CI; covariates held at mean.

Results

- **Group Differences:** Volleyball athletes achieved the highest CMJ heights (44.2 ± 7.7 cm), significantly exceeding Basketball, Soccer, and Recreational groups ($p < 0.001$). *(Figure 2)*
- **Asymmetry Magnitude:** Average takeoff force asymmetry ranged from ~6% to 7% across groups, with no significant differences observed ($p = 0.95$).
- **Reliability & Consistency:** CMJ height demonstrated excellent test-retest reliability (ICC = 0.97), while asymmetry showed good reliability (ICC = 0.92) but higher variability (CV ≈ 88–103%). Limb dominance was highly stable across sessions (Cohen's κ = 0.85). *(Figure 3)*
- **Predictors of Jump Height:** Peak force positively predicted CMJ height ($p = 0.007$), whereas higher body mass was negatively associated ($p < 0.001$).
- **Asymmetry Effects:** Overall, takeoff force asymmetry did not significantly predict jump height ($p = 0.138$). However, Soccer players showed a unique interaction, maintaining or slightly improving jump height despite increased asymmetry (interaction $p = 0.043$). *(Figure 4)*
- **Explained Variance:** The full linear mixed-effects model explained substantial variance in jump performance (marginal $R^2 = 0.465$).

Practical Applications

- **Assessment:** Takeoff force asymmetry can be reliably quantified and monitored using dual force plates, though its variability warrants cautious interpretation over time.
- **Training:** Reducing asymmetry may benefit athletes in sports emphasizing symmetrical jumping (volleyball, basketball), but may be less critical in soccer.
- **Individualization:** Practitioners should consider sport-specific demands and athlete profiles when designing interventions targeting force production and asymmetry.

Curriculum Vitae

Supplemental Materials