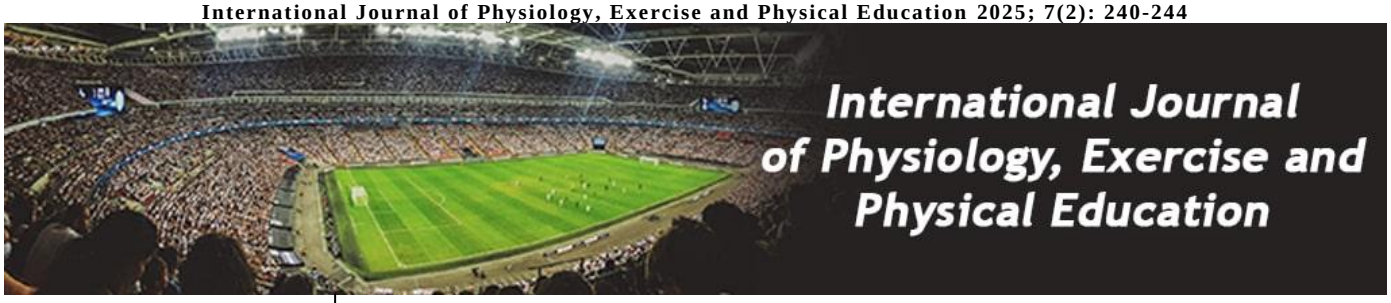


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# The relationship between lower limb unilateral muscular strength and landing technique (bilateral-unilateral) among junior basketball players

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**Abstract**
Evaluating each lower limb individually is fundamental in the physical and biomechanical analysis of athletes, particularly basketball players who frequently rely on unilateral actions such as running, jumping, and landing. Repeated use of one limb often leads to strength or neuromuscular control imbalances between the legs, which may reduce performance efficiency and increase the risk of functional injuries.
Unilateral strength assessments, including the single-leg squat and single-leg landing tests, provide accurate measures of strength, stability, and muscular symmetry, as well as related variables such as balance, knee angle, and pelvic control. Such evaluations offer a scientific foundation for designing targeted training and corrective programs that enhance bilateral functional integration and improve skill performance in basketball.
Improving movement quality remains a critical factor in developing agility, stability, and coordination among junior basketball players.

**Keywords:** Unilateral leg strength, landing technique (bilateral-unilateral), correlation, junior basketball players

## 1. Introduction

### 1.1 Research Significance

Lower-limb assessment is a fundamental component in the physiological and biomechanical evaluation of athletic performance. The strength and stability of the legs form the mechanical foundation for nearly all dynamic basketball movements such as sprinting, jumping, landing, and rapid changes of direction. Given that these movements predominantly involve unilateral lower-limb actions, traditional bilateral strength evaluations may overlook subtle asymmetries that influence mechanical balance and muscular coordination between the limbs.
Accordingly, individualized assessment of each leg through both qualitative and quantitative measures such as the Single-Leg Squat Test and the Single-Leg Hop Test offers precise insights into neuromuscular control, pelvic stability, and knee alignment during performance. The outcomes of such assessments provide essential diagnostic information for designing targeted training and rehabilitation programs aimed at correcting functional imbalances, enhancing motor efficiency, and reducing injury risk. Ultimately, this contributes to improving technical performance and long-term athletic development among junior basketball players.

### 1.2 Research Problem

Basketball is one of the most physically and technically demanding team sports, requiring players to maintain high levels of strength, speed, agility, and motor adaptability during constantly changing game situations. With the increasing intensity of competition and elevated physical demands, injury rates particularly in the lower limbs have risen due to repetitive jumping and landing actions.
Recent studies indicate that one of the primary contributing factors to such injuries is poor motor control resulting from deficits in neuromuscular stability and imbalances among the muscles surrounding the joints. In this context, functional movement assessments have

gained significance as precise scientific tools for the early detection of movement dysfunctions and weaknesses that affect athletic performance and injury prevention. Furthermore, bilateral and unilateral landing tests are considered key indicators of the neuromuscular system's efficiency in absorbing impact forces and distributing loads during dynamic movements.

### 1.3 Research Objectives

1. To determine the level of unilateral lower-limb muscular strength (right vs. left leg) among the study sample.
2. To assess the level of bilateral and unilateral landing ability by analyzing movement performance data and extracting statistical indicators reflecting neuromuscular control and stability efficiency.
3. To examine the significance of statistical differences between players with high and low levels of unilateral leg strength in relation to their bilateral and unilateral landing performance results.

### 1.4 Research Hypotheses

1. The researcher hypothesizes that there is a significant correlation between the results of the unilateral leg strength test and the quality of bilateral landing performance among junior basketball players, reflecting the role of motor efficiency in enhancing impact absorption and maintaining balance during movement.
2. The researcher hypothesizes that there is a significant correlation between the results of the unilateral leg strength test and the quality of unilateral landing performance among junior basketball players, indicating the influence of motor control efficiency in improving shock absorption and postural stability during performance.

### 1.5 Research Fields

- **Population:** Players of *Al-Hilla Sports Club* for the 2024-2025 season.
- **Setting:** *Hamza Nouri Sports Hall* - Babylon Governorate.
- **Time Frame:** From *July 15, 2025* to *August 15, 2025.*

## 2. Research Methodology and Field Procedures

### 2.1 Research Design

The researcher adopted a **descriptive correlational design** in this study due to its suitability for the research objectives, which aim to determine the nature of the relationships between test results among junior basketball players.

### 2.2 Research Population and Sample

The study sample consisted of 12 junior basketball players with an average age of 16.0 years, an average height of 181±4.5 cm, and an average weight of 77±5.2 kg, reflecting a body composition appropriate for the motor demands of basketball performance. The mean Body Mass Index (BMI) was approximately 23.5 kg/m², within the normal range for athletes in this age group.

Players were selected purposively to represent the competitive level of this category, ensuring that none had acute or chronic lower-limb injuries in the preceding six months and that all had been engaging in regular training of at least three sessions per week. Informed consent was obtained from all participants prior to testing, in accordance with ethical standards for field research.

### 2.3 Research Instruments and Tools

The following instruments and tools were used to collect data:

- Measuring tape
- Medical scale
- 40 cm high box for performing the landing test
- 30 cm high box for assessing knee angle in the *Single-Leg Squat Test*
- Digital video camera

### 2.4 Main Experiment

The main experiment for the study sample was conducted on Friday, July 15, 2025. The Single-Leg Squat Test was administered first to assess unilateral leg strength. Following this, players performed bilateral and unilateral landing tests, with each participant completing two attempts per landing type. The best attempt was selected based on standardized measurement techniques using high-resolution cameras and validated movement analysis models.

#### 2.4.1 Description of the Tests Used to Measure Research Variables

**1. Single-Leg Squat Test (SLST)**

The SLST is widely used in both sports and rehabilitation settings as a reliable indicator of lower-limb strength and neuromuscular control, as well as a tool to detect mechanical deviations between legs. The test is performed by having the athlete stand on one leg while flexing the opposite knee forward, then slowly descending until the knee reaches an angle of 60-90°, maintaining trunk alignment and pelvic stability. Multiple attempts are recorded, and the best performance is selected based on quantitative and qualitative criteria including depth of squat, knee alignment, pelvic stability, trunk control, and balance, where a higher score reflects superior neuromuscular control and lower-limb stability (Kotsifaki *et al*., 2020) [3].

**Scoring (Quantitative)**

| Measured Variable | Scientific Description | Performance Criteria | Score (out of 2) |
|---|---|---|---|
| Depth Control | Degree of knee flexion (60-90°) while maintaining movement control | Full stable squat = 2, Partial = 1, No squat or loss of balance = 0 | /2 |
| Knee Alignment | Tracking the knee over toes without excessive valgus or varus deviation | Perfect alignment = 2, Slight deviation = 1, Significant deviation = 0 | /2 |
| Pelvic Stability | Maintaining pelvis level without lateral drop or tilt | Completely stable = 2, Slight tilt = 1, Significant drop = 0 | /2 |
| Trunk Control | Maintaining upright trunk without excessive forward or lateral lean | Excellent = 2, Slight lean = 1, Large lean = 0 | /2 |
| Balance & Recovery | Ability to maintain balance without touching the free leg or losing control | Perfect balance = 2, Minor touch = 1, Loss of balance = 0 | /2 |

**2. Landing Error Scoring System (LESS)**

The LESS test is a precise analytical tool for evaluating landing mechanics. It records movement errors during an athlete's landing from a standardized platform, including knee alignment, weight distribution, trunk stability, and foot movement symmetry. Performance is captured using two cameras (front and side), and slow-motion analysis is used to identify deviations that may increase the risk of ligament injuries or neuromuscular dysfunction.

In this study, the LESS test was adapted to include unilateral landings (right and left) in addition to bilateral landings to reflect the mechanical specificity of basketball skills that often rely on single-limb actions (Padua *et al*., 2009) [6].

**LESS Test Setup and Procedure**

**Equipment**

- 40 cm high box
- Target line approximately 50% of the participant's body length in front of the box
- Two digital cameras (front and side)
- Observation sheet or slow-motion video software

**Steps**

1. Athlete stands on the box.
2. Jumps forward toward the target and lands with both feet directly on the ground.
3. Immediately descends into a partial squat upon landing.
4. Repeat if the attempt is invalid.
5. Each participant performs two attempts for bilateral landing and two attempts for unilateral landing (right and left).

**Scoring**

The LESS version used included 17 items (Padua *et al*., 2009) [6], considered highly effective clinically for detecting mechanical landing errors. Each item is scored 0 or 1 based on expert-defined criteria:

- 1 point for each detected error
- 0 points for correct performance

**3.5 Statistical Methods**

Performance evaluation incorporates multiple angles, assessing foot symmetry, knee position, trunk tilt, weight distribution, and post-landing stability.

"The data were processed and analyzed using the statistical software IBM SPSS Statistics, version 26, to perform the appropriate statistical tests and interpret the results."

**3. Presentation, Analysis, and Discussion of Research Results**

**3.1 Presentation and Analysis of Research Variables**

**Table 1. Descriptive Statistics of Research Variables**

| Variable | Mean | SD | Minimum | Maximum |
|---|---|---|---|---|
| Double-leg Landing | 11.58 | 1.83 | 9 | 15 |
| Right Single-leg Landing | 6.00 | 1.35 | 4 | 8 |
| Left Single-leg Landing | 6.00 | 2.29 | 3 | 9 |
| Right SLS | 5.08 | 2.02 | 2 | 8 |
| Left SLS | 5.00 | 2.17 | 2 | 8 |

The descriptive statistics show that the mean score for the double-leg landing was 11.58±1.83, with relatively limited variation, indicating a consistent performance level among the players for this variable. In contrast, the mean for single-leg landing was identical for both the right and left legs (6.00), but with a higher standard deviation in the left leg (±2.29) compared to the right (±1.35), reflecting greater variability in individual performance when using the left limb.

Regarding the Single-Leg Squat (SLS) test, the results showed a clear similarity between limbs, with the right leg averaging 5.08±2.02 and the left leg 5.00±2.17, indicating relative symmetry in strength and neuromuscular control between limbs. Overall, these results suggest that the sample's performance in motor skills tends to be consistent in bilateral tests, while greater variability appears in certain unilateral aspects, particularly with the left leg.

**3.2 Presentation and Analysis of the Limb Symmetry Index (LSI)**

**Table 2:** Limb Symmetry Index (LSI)

| Index | Mean | SD | Minimum | Maximum |
|---|---|---|---|---|
| Landing LSI | 81.15% | 11.38 | 60% | 100% |
| SLS LSI | 91.39% | 11.50 | 66.7% | 100% |

The results of the limb symmetry index indicate that the mean Landing LSI was 81.15%±11.38, which is below the reference threshold reported in the literature (≥90%), suggesting functional differences between the legs during single-leg landing. The minimum value reached 60%, a low percentage that may reflect muscular weakness or a notable mechanical imbalance in some players.

In contrast, the SLS LSI showed a higher mean (91.39%±11.50) with a range of 66.7% to 100%, indicating relatively better symmetry between limbs during the Single-Leg Squat test compared to landing. This result implies that the SLS test is more stable for assessing neuromuscular symmetry, while the single-leg landing test reveals subtle differences and mechanical control deficits in some players. Overall, the discrepancy between the two indices suggests that performance in high-load dynamic tasks, such as landing, is more prone to inter-limb variability compared to lower-load tasks, like the Single-Leg Squat.

**3.3 Presentation and Analysis of Paired Limb Differences (Right vs. Left)**

**Table 3:** Paired t-test for Limb Differences (Right vs. Left)

| Variable | t-value | p-value |
|---|---|---|
| Single-leg Landing | 0.00 | 1.000 |
| Single-Leg Squat (SLS) | 0.43 | 0.674 |

The results of the paired t-test assessing differences between the limbs showed t-values of 0.00 for single-leg landing and 0.43 for the Single-Leg Squat, with corresponding p-values of 1.000 and 0.674, respectively, which are well above the significance level of 0.05. These results indicate no statistically significant differences between the right and left legs in both tests, reflecting a certain degree of functional balance and comparable strength between the limbs among the players.

However, these indicators do not exclude individual differences within the sample. As previously shown in the Limb Symmetry Index (LSI), some cases fell below the reference threshold (90%), suggesting that overall symmetry may conceal subtle variations that require individual monitoring, particularly in training or rehabilitation programs.

### 3.4 Presentation and Analysis of Correlation Coefficients Between Variables

**Table 4:** Correlation Coefficients Between Variables

| | Double-leg Landing | Right Single-leg Landing | Left Single-leg Landing | Right SLS | Left SLS |
|---|---|---|---|---|---|
| Double-leg Landing | 1.00 | 0.52 | 0.76 | 0.65 | 0.75 |
| Right Single-leg Landing | 0.52 | 1.00 | 0.82 | 0.67 | 0.56 |
| Left Single-leg Landing | 0.76 | 0.82 | 1.00 | 0.65 | 0.67 |
| Right SLS | 0.65 | 0.67 | 0.65 | 1.00 | 0.95 |
| Left SLS | 0.75 | 0.56 | 0.67 | 0.95 | 1.00 |

From the table above, the following observations can be made:

**1. Moderate to strong correlations among landing skills**

- Double-leg landing correlates more strongly with left single-leg landing (0.76) than with right (0.52), indicating that performance in double-leg landing is more influenced by the left side.
- Right single-leg landing correlates strongly with left single-leg landing (0.82), reflecting relative neuromuscular balance between sides.

**2. Very strong correlations between SLS tests on both sides**

Right SLS with Left SLS = **0.95**, indicating a high similarity in strength and neuromuscular coordination between the limbs during single-leg squat testing.

**3. Moderate correlations between landing and SLS:**

Double-leg landing with right/left SLS ranges from 0.65-0.75, suggesting that double-leg landing performance partially reflects an individual's ability to control muscles while standing on one leg, but does not cover all aspects.

**4. Conclusion**

The different landing skills are variably correlated with each other, with higher neuromuscular coordination observed in SLS tests for each side. These results indicate that training players to improve single-leg neuromuscular balance may directly affect both single-leg and double-leg landing performance and highlight the importance of evaluating each limb separately.

**5 Discussion of Research Results**

The results of the sample showed a marked decline in both double-leg and single-leg landing tests, in addition to reduced strength levels in the single-leg strength test, indicating a combined deficit encompassing biomechanical, neuromuscular, and direct muscular strength aspects.

From a mechanical perspective, poor control of the center of mass and suboptimal lower-limb joint alignment particularly dynamic knee valgus reflect inefficiency in absorbing ground reaction forces. This is especially evident in single-leg landing, which requires greater balance and optimal load distribution (Hewett *et al*., 2005; Myer *et al*., 2014) [2].

From a neuromuscular perspective, studies have shown that impaired neuromuscular coordination and delayed muscle activation reduce the capacity for dynamic joint stabilization, while deficits in trunk and hip musculature compromise pelvic stability, leading to inefficient movement patterns (Paterno *et al*., 2007; Dingenen & Almonroeder, 2020) [7, 1].

This interpretation is further supported by the low scores in the single-leg strength test, confirming weakness in major lower-limb muscles (hip, knee, ankle) and, consequently, a reduced ability to progressively absorb forces and manage high dynamic demands (Kotsifaki *et al*., 2020; Markovic & Mikulic, 2010) [3, 4].

Based on these findings, it can be concluded that the observed deficits collectively highlight the critical need for comprehensive training programs focused on developing lower-limb muscular strength, enhancing trunk and hip stability, and improving neuromuscular coordination through dynamic balance and plyometric training to optimize landing mechanics and reduce injury risk.

**6. Conclusions and Recommendations**

**6.1 Conclusions**

**1. Homogeneity of the General Physical Level of the Sample**

Descriptive statistics showed that the mean score for double-leg landing was 11.58±1.83, indicating a relatively uniform level of explosive strength and mechanical control among the players.

**2. No Significant Differences Between Lower Limbs**

The t-values for single-leg landing ($t = 0.00$, $p = 1.000$) and the Single-Leg Squat ($t = 0.43$, $p = 0.674$) were above the significance level (0.05), indicating no statistically significant differences between the right and left legs in functional performance.

**3. Reduced Limb Symmetry Index in Single-Leg Landing**

The mean Landing LSI was 81.15%±11.38, below the international reference threshold (≥90%), suggesting functional asymmetry in some players, which may reflect neuromuscular control deficits or mechanical imbalance during landing.

**4. Improved Limb Symmetry Index in Single-Leg Squat**

The mean SLS LSI was 91.39%±11.50, approaching the ideal level, indicating that the Single-Leg Squat test is more stable and less sensitive to marked inter-limb asymmetries compared to landing.

**5. Strong Correlations Between Different Tests**

Correlation analysis revealed strong positive relationships between double-leg landing and left single-leg landing ($r = 0.76$), double-leg landing and left SLS ($r = 0.75$), and a very strong correlation between right and left SLS ($r = 0.95$), confirming the consistency of the measurements and the validity of the assessment tools used for evaluating strength and control.

**6. Sample Performance Reflects an Acceptable Level of Motor Control**

The mean values for the Single-Leg Squat tests (Right = 5.08±2.02, Left = 5.00±2.17) indicate moderate to good motor control performance, with potential for improvement through strength and balance training.

## 7. Recommendations

### 1. Training Recommendation

Incorporate single-leg strength and balance exercises into basketball training programs to improve the Limb Symmetry Index (LSI) and enhance neuromuscular control, particularly in cases where LSI falls below 85%.

### 2. Preventive Recommendation

Monitor players with Landing LSI values below 80% using corrective mechanical programs focusing on hip muscles (Gluteus Medius) and knee control during landing to reduce future injury risks, particularly ACL injuries.

### 3. Research Recommendation

Expand sample sizes in future studies to include different age and skill groups, and conduct motion analysis using three-dimensional imaging systems to achieve more precise assessments of mechanical differences.

### 4. Practical Recommendation

Adopt the Single-Leg Squat test as a routine assessment tool in clubs and rehabilitation centers due to its high reliability and strong correlation with landing outcomes ($r > 0.65$).

### 5. Future Recommendation

Conduct comparative studies on the effects of functional strength programs versus dynamic stability programs on improving LSI and motor performance outcomes.

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