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The Asymmetry Level of Hamstrings Strength in Female U16 Basketball Players

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Authors' Contribution: A: Study design, B: Data collection, C: Data analysis, D: Manuscript preparation, E: Discussion and conclusion

ABSTRACT

Study aim(s): This study aims to assess hamstring strength asymmetry in female basketball players under 16 years old using both bilateral and unilateral Nordic Hamstring Test. The goal is to identify right-left leg strength differences that may influence injury risk and performance, yet often go undetected in regular training.
Methods: The observational study, with a cross-sectional design includes 10 female basketball players under the age of 16 who train regularly with the "United Basketball" U16 team, under the framework of the Kosovo Basketball Federation (KBF). Hamstring strength asymmetry was assessed using the bilateral and unilateral Nordic Hamstring Tests using, with data collected via the My Jump 3 application. The measured parameters included torque (Nm), percentage of maximum torque (% of max τ), breakpoint angle (º), and asymmetry level (%). Data were analyzed using SPSS version 27. The statistical methods applied the Shapiro-Wilk test, descriptive statistics, percentiles, Pearson correlation, independent t-test, and a standard formula for calculating asymmetry level.
Results: A significant negative correlation was found between body weight, attributable to muscle mass, and asymmetry ($r = 0.681$, $p = 0.030$). BMI showed a similar non-significant trend ($r = 0.614$, $p = 0.059$). In contrast, height and lever length exhibited weak correlations with asymmetry. Torque was higher in the right leg (455.24 Nm) compared to the left leg (370.85 Nm). The measured asymmetry was 5.09%, indicating a slight dominance of the right leg.
Conclusion: In U16 female basketball players, a 5% asymmetry between the left (370 Nm, 102.3°) and right leg (455 Nm, 103.5°) in torque and breakpoint values suggests an acceptable level of functional variation. This asymmetry is likely influenced by muscle mass, which contributes to strength balance and neuromuscular control. These findings highlight the importance of targeted unilateral hamstring training to reduce injury risk in dynamic, sport-specific movements.

Keywords: Nordic Hamstring Test, Strength Imbalances, Injury Prevention, Female Athletes, Basketball

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INTRODUCTION

Hamstring strength is crucial in basketball, as it directly supports sprinting and jumping performance. Weakness in this muscle group increases the risk of hamstring strain injuries due to the sport's high-speed demands and extreme muscle stretching. However, its development can be limited because the hamstrings are not part of the primary antigravity muscle group. Previous studies have shown that in girls, hamstring strength does not increase spontaneously after the age of 11, either during the adolescent growth spurt or to the same extent as quadriceps strength following menarche. According to the literature, hamstring strength in girls lags behind by age 11, increasing the risk of ACL and hamstring injuries, particularly as ACL injury rates rise from age 12 and are 1.4 times higher in girls. Therefore, early hamstring strengthening is crucial, although most training research has focused on boys or older athletes [1]. Strength asymmetry refers to an imbalance between limbs or muscle groups, and its impact on injury risk and sports performance has been extensively investigated in the literature, particularly within strength and conditioning research [2]. Previous studies have highlighted the importance of hamstring function for athletic performance, particularly in terms of explosive strength, which is crucial in basketball for actions such as sprint acceleration through increased production of horizontal ground reaction force (GRF) [3]. Nordic hamstring exercise (NHE) training has been shown to produce sustained improvements in hamstring function in athletes, which can translate to enhanced 5 m and 10 m sprint performance as well as increased maximum countermovement jump (CMJ) height. In addition to monitoring overall hamstring strength, recent research has increasingly focused on inter-limb hamstring strength asymmetry. Studies have shown that an asymmetry greater than 15% may significantly increase an athlete's risk of hamstring injury [2].

Hamstring injury-risk assessment has primarily relied on isokinetic dynamometry; however, its high cost and limited availability restrict widespread use. Therefore, field-based alternatives for assessing eccentric hamstring strength are needed [4]. The Nordic hamstring exercise (NHE) is a widely method for developing hamstring strength. It is a self-controlled, bodyweight-based variation of the traditional leg-curl exercise. NHE requires no equipment and provides an eccentric training stimulus through the resistance generated by the weight of the upper body [1]. The most commonly used eccentric strengthening exercise in research aimed at preventing hamstring injuries is the Nordic hamstring exercise. During testing, the athlete's ankles are secured using braces attached to load cells, which measure the maximal eccentric hamstring force as the athlete leans forward and resists forward motion for as long as possible. The Nordic hamstring exercise is designed to be supramaximal, meaning that the external load from gravity acting on the upper body should eventually exceed the athlete's maximal eccentric hamstring strength. A key prerequisite for Nordic hamstring test devices is that the athlete reaches this 'critical point' during the movement. However, some athletes are able to control the forward falling motion throughout the entire range of motion, thereby never reaching this point. These athletes will never reach the 'critical point,' and as a result, the test cannot accurately measure their maximal eccentric hamstring strength as intended [5]. According to the literature, incorporating hamstring exercises such as Nordic curls (also known as Nordic hamstring lowers) into a training program has been shown to improve hamstring strength by approximately 11%. Theoretically, the greater the range achieved during a Nordic hamstring lower, the greater the individual's eccentric hamstring strength, as the gravitational moment progressively increases throughout the movement. Therefore, the 'break point', the angle at which the individual can no longer resist the increasing gravitational load and begins to

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fall, may serve as a useful indicator for assessing eccentric hamstring strength [4].

High-intensity sports like basketball require muscular balance and strength, as hamstring asymmetry significantly increases the risk of injury, particularly in developing youth athletes. The focus of this study stems from stems from concerns, with specific attention to female basketball players and the complexity of hamstring-strengthening exercises. Female basketball players under the age of 16 represent a unique population with distinct needs, highlighting the importance of continuous monitoring of their physical condition. During this developmental phase, rapid changes in muscle structure, hormonal balance, and neuromuscular coordination make young athletes more susceptible to injury, particularly when preventive measures are not properly implemented. In this context, the absence of objective tools for assessing muscle strength and inter-limb symmetry may lead to overestimation of physical condition and the overlooking of asymmetries, which can develop into significant risk factors over time. In addition, the specific mechanics of hamstring muscle activation limit the range of effective exercises both with and without equipment, often resulting in insufficient loading of these muscles. Consequently, inadequate training stimulus can lead to strength deficit, which are commonly associated with a significantly increased risk of injury.

The primary objective of this study is to assess the level of hamstring strength asymmetry in female basketball players under the age of 16 by applying the Nordic Hamstring Test in both bilateral and unilateral formats. This assessment aims to identify potential differences in muscle strength between the right and left legs, differences that are often overlooked during routine training but can significantly impact both injury risk and sports performance. The study seeks to generate precise data on each athlete's hamstring strength profile, enabling the early detection of functional imbalances. The study also aims to emphasize the importance of early identification of functional asymmetries, providing a foundation for timely intervention through the implementation of personalized preventive and corrective training programs.

METHODS

Research Design

This observational study employs a cross-sectional design to assess the level of hamstring muscle strength asymmetry in female basketball players under the age of 16. It focuses on analyzing functional muscular differences at a single point in time through the application of the Nordic Hamstring Test in both bilateral and unilateral formats

Study Sample

This study includes 10 female basketball players under the age of 16, who regularly train with the "United Basketball" basketball team in the U16 category. The players are members of United Basketball, a club competing in the girls' U16 division under the Kosovo Basketball Federation (KBF). Most of the players joined the club 2 to 3 years ago, but prior to that, they had participated in other activities involving basketball. The athletes follow a structured program, including tactical training 4 to 5 times per week during the season and technical training 3 times a week in the off-season, designed to develop both individual skills and team play.

Measurement tools

Height was measured from the floor to the top of the head while participant stood barefoot, upright,

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with the head aligned in the Frankfurt plane and back against a wall, using a mobile stadiometer accurate to 1 mm [6].

Body Weight was measured with a Tanita BC 545N device, suitable for ages 5 to 99, during morning hours before eating or drinking. Athletes were barefoot and dressed in sportswear during the measurement.

Nordic Hamstring Tests

The "My Jump Lab" application, a validated tool for biomechanical analysis in sports, was used to collect data. This test assess hamstring strength through the Nordic Hamstring Exercise. First, the athlete is recorded from the side while crossing their hands on the chest. The evaluator then identifies the first frame where the hands begin to move away from the chest. Three markers are placed to calculate the Nordic angle and estimate the torque.

Test protocol

After completing a warm-up set of submaximal bilateral Nordic Hamstring Exercises (NHEs), participants performed two sets of three maximal NHEs in both bilateral and unilateral formats. During unilateral contractions, only the limb being tested was secured with an ankle brace. Bilateral NHEs were always performed first, while the order of limb testing during unilateral NHEs was randomized for each participant. There was a two-minute rest period between sets. During the test, the player's ankles are secured using braces attached to load cells, which measure maximal eccentric hamstring force as the athlete leans forward and resists falling for as long as possible. The Nordic hamstring exercise is designed to be supramaximal, and a key prerequisite for Nordic hamstring test devices is that the athlete reaches a 'critical point', where the gravitational load from the upper body exceeds their maximal eccentric hamstring strength [5].

Measured parameters

Torque (Nm): also known as the moment of force, is the rotational equivalent of linear force. It describes the tendency of a force to cause an object to rotate around an axis. As a vector quantity, torque has both magnitude and direction [7].

Percentage of maximum torque (% of max τ): refers to the proportion of torque generated relative to the theoretical maximum torque required to maintain a fully extended position.

Breakpoint angle (⁰): The angle between the thigh (femur) and the shank (tibia/fibula) at the moment the athlete can no longer maintain the position during the Nordic hamstring test.

Asymmetry level (%): The percentage difference in force output between the left and right leg during the unilateral Nordic hamstring test.

Data analysis

Data analysis was conducted using SPSS version 27. The normality of the data was assessed using the Shapiro-Wilk test, which confirmed a normal distribution ($p > 0.05$). Descriptive statistics were used to summarize the general characteristics of the dataset, and percentiles were calculated to establish normative values for the sample. To explore the relationship between asymmetry levels in the Nordic hamstring test and body composition variables, Pearson correlation analysis was performed. An independent samples t-test was used to compare performance differences between the right and left legs. The asymmetry level between limbs was calculated using a standard formula.

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FINDINGS

Table 1. Descriptive Statistics for Body Composition and My Jump Metrics Related to the Nordic Hamstring Test

Descriptives		W (kg)	H	BMI (kg/m2)	Lever (m)
Mean		59.7	169.8	20.6	1.24
Std. Deviation		8.11	7.84	1.98	.06
Skewness		-.234	.921	-.682	1.075
Kurtosis		1.059	.477	.115	.081
Range		30.0	24.0	6.70	.18
Minimum		44.0	162.0	16.80	1.19
Maximum		74.0	186.0	23.50	1.37
Percentiles	25^{th}	55.2	162.0	19.2	1.19
	50^{th}	59.0	168.5	21.3	1.22
	75^{th}	64.5	176.0	22.1	1.30

Based on Table 1, the skewness and kurtosis values for all variables fall within acceptable ranges (typically, between -2 and +2), indicating that the data are approximately normally distributed and that there is homogeneity within the sample group.

Table 2. Descriptive Statistics for Nordic Hamstring Test Variables

Descriptives		Left Torque (Nm)	Break Point (0)	Right Torque (Nm)	Break Point (0)	Asymmetry (%)	Torque Bilateral (Nm)	% of Max Torque (%)
Mean		370.8	102.3	455.2	103.5	5.09	474.3	99.63
Std. Deviation		174.07	6.01	125.13	8.81	3.83	80.58	.614
Skewness		-.336	.425	-1.447	-.388	.537	.650	-2.484
Kurtosis		-.701	-.959	4.153	-1.553	-1.242	1.388	6.578
Range		532.0	16.9	486.1	23.77	10.70	297.0	2.00
Minimum		111.5	94.4	153.3	91.13	.65	344.0	98.00
Maximum		643.5	111.3	639.4	114.90	11.35	641.0	100.00
Percentiles	25^{th}	191.2	97.6	430.1	94.0	1.51	431.5	99.52
	50^{th}	425.2	101.6	465.5	106.6	3.92	465.5	99.90
	75^{th}	494.0	108.5	510.9	110.2	9.08	509.2	100.00

Table 2 shows that the mean torque is higher in the right leg (455 Nm) compared to the left leg (371 Nm), with an average asymmetry of about 5%. Breakpoint angles are similar between legs, averaging around 102°. Torque values exhibit considerable individual variability, as indicated by the high standard deviations. Overall, bilateral torque averages near maximal effort (~99.6%), consistent with the observed asymmetry level.

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Table 3. Correlation between Body Composition Features and Asymmetry

Variables	Sig	Asymmetry (%)
W (kg)	r	-.681*
	p	.030
H	r	-.392
	p	.263
BMI (kg/m2)	r	-.614
	p	.059
Lever (m)	r	-.215
	p	.552

Results from Table 3 show that weight has a significant negative correlation with asymmetry (r = -0.681, p = 0.030). Height, body mass index, and lever length exhibit trends toward negative correlations, but these are not statistically significant (p > 0.05), suggesting no strong relationship with asymmetry in this sample.

Table 4. Side-to-Side Comparison of Torque and Breakpoint Angle in Lower Limbs

Parameters	Legs	X̄±SD	Mean Diff.	Diff. %	Sig	% of Max Torque	Asymmetry %
Torque (Nm)	L	370.8±174.07	84.39	22.76	.231	99.6	5.09
	R	455.2±125.13					
Breakpoint (^{0})	L	102.3±6.01	1.21°	1.18	.724		
	R	103.5±8.81					

Table 4 shows that the right leg torque (455.24 Nm) was higher than the left leg (370.85 Nm) by 22.76%, although this difference was not statistically significant (p = .231). The asymmetry level was 5.09%, which falls within acceptable limits, with both legs reaching approximately 99.6% of maximum torque. Breakpoint angles were similar between legs (left: 102.34°, right: 103.55°), with no significant difference observed (p = .724), indicating balanced neuromuscular control.

DISCUSSION

Based on the results of this study, which aimed to determine the level of hamstrings strength asymmetry between the right and left legs, the mean torque produced by the right leg (455.24 Nm) was notably higher than that of the left leg (370.85 Nm), indicating a degree of lateral dominance or imbalance (see table 4). Variations in maximal torque production between legs may be attributed to differences in muscle mass, contractile properties (such as fiber type composition and muscle architecture), and/or the level of maximal neural activation [8].

This is further supported by the mean asymmetry value of 5.09%, with individual values reaching up to 11.35%, which may be clinically significant, particularly in the context of injury prevention and rehabilitation. Such imbalances in hamstring strength can elevate injury risk by increasing mechanical stress on joints and soft tissues, potentially leading to overuse injuries or acute incidents such as ligament sprains and muscle strains [9]. The literature indicates that while some asymmetry is expected in athletes, values exceeding 10% may require targeted corrective training. Our findings revealed a high degree of asymmetry between limbs in a healthy population, with more than half of the participants exceeding 10% asymmetry in peak hip and knee flexion and adduction moments [10] .

The breakpoint angles which indicate the joint angle at which torque output begins to decline, are relatively consistent between limbs, with the right leg showing a slightly higher mean than the left. This suggests symmetrical neuromuscular control near full extension. However, average torque values are higher in the right leg compared to the left, indicating a potential strength imbalance. Breakpoint angles are similar between sides, averaging 102.34º for the left and 103.55º for the right, suggesting consistent neuromuscular control across limbs. A study of young male professional soccer players found nearly all participants (97.2%) exhibited at least one muscle imbalance greater than 10% in either the quadriceps or hamstring at certain speeds. This highlights that subtle strength asymmetries are common among athletes and may potentially impact both performance and injury risk [11].

Based on the results of the study, increases in body weight are associated with decreases in asymmetry. While this may seem counterintuitive, the observed weight gain in these athletes is likely attributable to increased muscle mass rather than fat. Greater muscle mass typically leads to enhanced strength and improved muscular balance, which could explain the reduced asymmetry observed in the data. Although the correlation with BMI was moderately negative, indicating a similar trend, it was not statistically significant. Nonetheless, this pattern supports the idea that muscle growth plays a key role. Muscle development is a crucial component of conditioning in many sports, as there is a well-established link between muscle size and the strength it can generate [12-13]. Improved physical development, particularly increased muscle mass may help reduce strength imbalances in U16 female basketball players. To better understand the relationship between body composition and asymmetry, future analyses should examine correlations with fat percentage and muscle mass separately. This would clarify whether reduced asymmetry is primarily driven by muscle gains rather than other components of body weight. Body composition plays a significant role in athletic performance, with fat-free mass and lean soft tissue mass being closely linked to strength [14].

The average torque was higher in the right leg compared to the left, with a mean difference of 84.39 Nm (22.76%). Although this indicates a notable strength imbalance, the difference was not statistical significance. The asymmetry percentage was 5.09%, which falls within acceptable limits but still suggests a tendency toward right-side dominance. The percentage of maximal torque achieved was very high at 99.6%, indicating balanced effort between the right and left legs. According to motor control theory, bodily asymmetries can serve as constraints that influence movement patterns. When such imbalances are present, athletes may unintentionally develop compensatory movement habits that increase their risk of injury [15].

Interlimb asymmetry in the lower limbs increases the risk of injury, as the stronger leg may experience overuse stress while the weaker leg struggles to cope with normal strain, rendering both more vulnerable [2]. Therefore, imbalances not only in force production or movement mechanics, but also in the speed of force generation, may represent a significant injury risk. Current literature links hamstring injuries primarily to high-speed stretching mechanisms [16; 17].

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Within return-to-play protocols following ACL injuries, multiple studies have identified asymmetry thresholds of 10% and 15% as indicative of acceptable interlimb differences. Athletes exhibiting asymmetries below these thresholds are generally considered at reduced risk and are cleared to resume competitive activity [18]. Studies have shown that activity on one side of the body can influence the other side, due to the brain and nervous system's interconnected structure. The distinction between controlling a single limb and coordinating both limbs lies in how the nervous system manages and communicates signals across hemispheres [19]. Since movements of each limb are primarily controlled by the opposite hemisphere of the brain, differences in injury rates between the dominant and non-dominant legs may be attributed to variations in neuromuscular control [20].

In summary, the torque difference suggests a strength imbalance favoring the right leg, whereas the similar break point angles indicate symmetrical joint control. This underscores the importance of monitoring unilateral strength to prevent imbalances that may affect performance or increase injury risk. Leg dominance, typically the preferred leg for actions such as kicking or stabilizing is common among athletes in invasion sports, who often rely more heavily on one leg for technical tasks. This repeated use can contribute to strength asymmetries, although the exact impact on performance remains unclear [21; 22]. Unilateral (UNI) training enhances neuromuscular activation in key muscles such as the gluteus medius, hamstrings, and quadriceps. However, its inherent instability may limit maximal strength development and the amount of external load that can be safely applied [23]. Research indicates that UNI training improves single-leg strength and power, often yielding greater gains in movements like jumping when compared to bilateral training, particularly in sports requiring rapid, single-leg actions [24]. Additionally, it also increases muscle activation and isometric strength in the trained limb [25].

CONCLUSION

The bilateral mean torque of U6 female basketball players is 474 Nm, with the left leg producing 370 Nm and the right leg is 455 Nm. In terms of break point angle, the left leg registers 102.30, while the right leg shows 103.50. This result is an asymmetry level of approximately 5.0% between the right and left legs. As discussed in the literature, while some degree of asymmetry is common among athletes, values below the 10-15% threshold are generally not associated with increased injury risk. Therefore, the observed 5% difference likely represents acceptable functional variation rather than a pathological imbalance.

Increased body-weight, particularly when attributed to greater muscle mass is associated with reduced asymmetry, likely due to enhanced strength and muscular balance. As discussed in a previous section, this relationship suggests that gains in muscle mass, reflected in higher body weight, may promote bilateral strength balance and mitigate asymmetries. Greater lean mass has been shown to improve neuromuscular control and overall force production further supporting this association.

While the torque difference indicates a functional imbalance favoring the right leg, the similarity in break point angles suggests symmetrical joint control and behavior across limbs. These findings emphasize the importance of monitoring unilateral strength to prevent imbalances that may increase injury risk or impair performance. Consequently, future research should focus on optimizing unilateral training protocols to maximize neuromuscular activation benefits while addressing external load limitations, especially in sports demanding single-leg power and stability.

Imbalances in both force and the speed of force production may elevate injury risk, with hamstring injuries frequently associated with high-speed stretching.

Hamstring muscle mass is crucial in basketball due to the sport's reliance on fast, explosive, and dynamic movements. These muscles play a key role in unilateral actions such as layups and bilateral movements like jump shots, as well as in acceleration, deceleration, and changes of direction. Weak or undertrained hamstrings increase injury risk, particularly during the high-speed stretches common in basketball. Movements including layups, jump shots, defensive slides, sprints, and sudden directional changes demand hamstring strength for hip extension, knee stabilization, and explosive power. Despite this importance, hamstrings often receive less targeted training compared to other muscle groups especially regarding unilateral strength, despite its critical role in one-legged movements to the sport.

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