Age-Related and Side-Dependent Differences in Hip Range of Motion among Female Indian Athletes: Establishing Reference Values

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Abstract: Restricted hip mobility and flexibility are always associated with increased risk for lower extremity injury and poor athletic performance in female athletes. Reference values for hip motions in female athletes by age and sports are lacking. The primary aim of the study is to document the active and passive range of motion of hip joint among adolescent and adult Indian female athletes. Next, to compare between the sides and age group in the same population. This is a cross-sectional study involving 498 healthy female athletes of age group 15-21 years involved in the high impact sports were conveniently selected for the measurements of hip active and passive range of motion with a Universal goniometer. Participants with recent history of musculoskeletal injury and neurological pain syndromes were excluded from the study. Comparing the baseline values of active and passive range of motion of hip joint, between adolescent and adult female athletes, revealed a significant difference ($p<0.05$) in both dominant and non-dominant leg except for passive hip abduction ($p>0.05$). However, adolescents demonstrated higher hip flexion, internal rotation, and external rotation, and adults showed greater hip extension. Active and passive reference values for hip range of motion is documented for South Indian female athletes in relation to age and high impact sports. Future research involving injury prediction, prevention and rehabilitation protocol among female sports can utilize these values.

Keywords: Hip movement, Female adolescent athletes, Female adult athletes, Normative values, Cross-sectional study.

1. INTRODUCTION

Over the years there has been a consistent raise in population in the number of female athletes in India, but there is a big gender gap in the sports industry. There are many sports sectors where women can play, and Indian women have made notable process and have emerged successfully. Physical exercise, training and their participation in sports play a vital role in their health and balanced life. A substantially bigger proportion of the population currently consists of female athletes. There is an increase trend of 20% growth over the past 50 years, and it is expected constantly raise in the following years.[1]

Factors such as genetic and hormonal variances influencing in genders determents once individual sports performance depending upon height, body mass, body fat, muscle mass, aerobic capacity and anaerobic threshold. Some authors used Nonlinear models with sparse data was used in studying physiological limits of various sporting activities. Few other authors suggested have found that gender gaps may disappear over time in race records. Furthermore, comparing to men, women have shown lower record values. A fact which prevails states that restriction of women's performance remains subpar to men. Thus, when both genders reach their physiological limits, gender disparities will likely be eliminated.[2]

High level performing female athlete follow steady diet along with lifestyle guidelines.in order to train for nonstop for weeks prior to sports event, they undergo stern schedule enhancing their daily training and recovery goals. They follow a predetermined diet to acquire the required quantity of nutrition for exercise and muscle repair after workout.

Athletes, like any other individual, tend to lose social and emotional relationship sometimes when they become too focused on their training objectives. Hip function influences the performance and overall health of female athletes. Hip joint influences various sport activity movements such as running, jumping, cutting and pivoting. Optimal hip function is necessary for power generation, maintaining balance and reducing injury risk. [3]

According to Powers (2010) article, states that improper biomechanical position of hip can lead to knee problems. It also emphasizes the alteration in lower limb joints and elevated risk of knee problems. Specifically in female athletes can be prone to injury as a result of poor hip function caused by hip strength and control. Furthermore, studies have stated that hip muscles such as abductors weakness and tight hip flexors causes imbalances, aggravating several illnesses such as patellofemoral pain syndrome, iliotibial band syndrome and anterior cruciate ligament (ACL) injuries.[4]

Tyler et al (2001) study discovered that female athletes with hip weakness are prone to non-contact ACL injuries. Authors stress significance of good hip strength and neuromuscular control to reduce the risk of ACL injuries and improve athletic performance.[5]

Several reasonable facts that necessitate the reference values for hip range of motion among female athletes are for maximal athletic performance, injury prevention and overall functional movement with requisite hip mobility and flexibility. Specifically female athletes have restricted range of motion which is linked to increased risk of lower limb injuries. Deficient hip mobility can lead to abnormal movement patterns and compensatory mechanisms, impacting undue strain on surrounding tissues such as knee and ankle. Several injuries of lower limb targeting joints like patellofemoral and soft tissue structures like Iliotibial band, Cruciate ligaments, collateral ligaments., etc. has been linked to inadequate hip range of motion as stated in few studies.[6,7.]

In our day-to-day functional activities and movements, hip mobility is necessary. Proper squatting, lunging, and hip hinge mechanics are required for activities such as lifting, running and changing directions. These movements are made accessible by adequate hip range of motion. Deficient hip mobility does not allow athletes to perform movements free and effectively. This can lead to compensatory changes in structural pattern, increasing the risk of injury and executing low muscle performance.[8]

Since there is small amount of research evidence done to determine the normal hip range of motion in female athletes, to analyze normative data may help predicting the associated risk or health complication, thus the study aims to determine the normative values of hip range of motion in female athletes.

2. METHODS

Study Design

In accordance with the guidelines of the Helsinki Declaration of 1975, a cross-sectional study was designed to measure the hip motions of female athletes. After obtaining clearance from the institutional ethical committee (Ethical Clearance Number:1666/IEC/2019), participants were recruited from major sports universities in Tamil Nadu. Parents of female athletes under the age of 18 were provided with study details and asked to provide consent for their daughters to participate. Proper written consent was obtained from all female athletes before data collection. Two physical therapists with three years of experience were recruited as examiners to collect the data over a three-year period from October 2020 to September 2022.

Subject Allotment

A total of 498 female athletes between 15 to 21 years of age participating in high impact sports were included in the study. Individuals with a history of pregnancy, urogenital surgery, recent musculoskeletal injuries (within the past 6 months), neurological disorders related to the bladder, hip joint pain or muscle guarding, medical conditions such as juvenile diabetes, and known congenital urogenital problems were excluded from the study.

Procedure

For data collection, active and passive range of motion (ROM) of the hip joints were measured using a Universal goniometer by experienced physical therapists. Measurements were taken in the supine lying position and included hip abduction, hip flexion with the knee flexed to 90 degrees, as well as internal and external rotation with both the hip and knee at 90 degrees. Separate measurements were taken for the dominant and non-dominant sides. Hip extension was measured in the prone lying position. During measurements, one examiner stabilized the proximal joints while the other measured the range of motion. Each measurement was taken three times by the same examiner, and the average was calculated for analysis.

During Hip flexion, the knee joint was flexed to 90 degrees by the examiner, and the subject was instructed to flex the hip as much as possible for active range of motion measurement. The examiner then passively moved the limb to the end range for passive range of motion measurement. In Hip abduction, the athlete actively moved the limb away from the body, and the examiner took passive measurements while ensuring the pelvis remained level. For internal and external rotation, with the hip and knee flexed to 90 degrees, the athletes were instructed to move their legs inward and outward, respectively, for measurement. The other examiner maintained the hip and knee at 90 degrees during both active and passive measurements.

In the prone lying position, one examiner stabilized the pelvis at the level of the PSIS (posterior superior iliac spine) while the athlete lifted the leg with the knee extended for active range of motion measurement. The other examiner passively lifted the leg for measurement.

Statistical Analysis

The collected data was tabulated, and the statistical analysis was performed using SPSS for windows v.13 (SPSS Inc., Chicago II., USA). Descriptive statistics like frequency and percentages, and interferential statistics like t-tests were performed to analyze the data. At 95% confidence interval, P<0.05 is followed for the level of significance.

Table 1: Demographic characteristics of adult and adolescent female athletes

DEMOGRAPHICS	ADULT FEMALE ATHLETES				ADOLESCENT FEMALE ATHLETES			
	Min	Max	Mean	SD	Min	Max	Mean	SD
AGE (Years)	18.00	21.00	20.01	.89	15.00	17.00	16.13	.72
WEIGHT (Kg)	46.00	65.00	55.04	4.47	46.00	64.00	54.26	4.13
HEIGHT (cm)	154.00	170.00	160.95	3.89	154.00	169.00	159.21	2.83
BMI	18.20	24.52	21.23	1.37	18.20	24.34	21.39	1.31
MENARCHE	11.00	14.00	13.64	6.01	11.00	14.00	13.76	6.68
	Frequency (percentage)				Frequency (percentage)			
SPORTS SPECIALITIES:								
VOLLEYBALL	53 (18.5%)				43 (18.6%)			
BASKETBALL	58 (20.3%)				48(20.8%)			
KABADI	53 (18.5%)				43 (18.6%)			
FOOT BALL	55 (19.2%)				41 (17.7%)			
BALLBADMITON	22 (7.7%)				22 (9.5%)			
RUNNERS	45 (15.7%)				34 (14.7%)			
EXPERIENCE								
<2 YEARS	1 (0.3%)				17 (7.4%)			
2-3 YEARS	192 (67.1%)				204 (88.83%)			
>3 YEARS	93 (32.5%)				10 (4.3%)			
DOMINANT								
RIGHT	259 (90.6%)				210 (90.9%)			
LEFT	27 (9.4%)				21 (9.1%)			

SD – Standard Deviation

Table 2: Comparison of AROM between dominant and non-dominant leg in adolescent and adult female athletes

Hip AROM (Degrees)	Age group (Years)	Dominant Mean ± SD	Non-Dominant Mean ± SD	MD	t value	p value*
Hip Flexion (HF)	15-17	126.70±1.86	124.46±1.97	2.24	16.8	0.000
Hip Extension (HE)		22.90±1.34	22.64±0.89	0.26	2.77	0.006
Hip Abduction (HABD)		43.41±1.15	40.79±1.37	2.62	29.85	0.000
Hip Internal Rotation (HIR)		44.41±1.47	41.85±1.27	2.57	21.56	0.000
Hip External Rotation (HER)		50.71±3.03	50.38±2.14	0.32	1.417	0.158
Hip Flexion (HF)	18-21	123.32±1.78	121.84±1.78	1.49	11.945	0.000
Hip Extension (HE)		24.22±0.91	23.00±0.79	1.22	15.919	0.000
Hip Abduction (HABD)		44.40±0.76	40.44±0.95	3.95	44.825	0.000
Hip Internal Rotation (HIR)		45.24±1.41	42.98±1.08	2.26	21.024	0.000
Hip External Rotation (HER)		49.88±0.77	44.86±1.00	5.02	67.138	0.000

AROM – Active Range of Motion, SD- Standard Deviation, MD- Mean Deviation, HF – Hip flexion, HE- Hip Extension, HABD- Hip Abduction, HIR- Hip Internal Rotation, HER- Hip external Rotation, * - Significance level at p<0.05 (t-test performed)

Table 3: Comparison of PROM between dominant and non-dominant leg in adolescent and adult female athletes

Hip PROM (Degrees)	Age Group (Years)	Dominant Mean ± SD	Non-Dominant Mean ± SD	MD	t value	p value*
Hip Flexion (HF)	15-17	130.99±1.54	129.58±1.87	1.42	13.08	0.000
Hip Extension (HE)		24.52±1.02	24.58±1.12	-0.07	-0.886	0.377
Hip Abduction (HABD)		46.55±1.68	46.61±1.69	-0.7	-0.466	0.642
Hip Internal Rotation (HIR)		48.97±0.89	48.79±0.85	0.18	2.252	0.025
Hip External Rotation (HER)		55.82±3.45	53.78±0.82	2.04	8.889	0.000
Hip Flexion (HF)	18-21	128.44±2.21	125.23±6.39	3.21	8.84	0.000
Hip Extension (HE)		25.40±0.58	23.52±0.63	1.88	38.02	0.000
Hip Abduction (HABD)		46.72±1.31	46.63±1.32	0.09	3.31	0.001
Hip Internal Rotation (HIR)		49.17±1.02	49.35±0.97	-0.18	-2.11	0.035
Hip External Rotation (HER)		57.96±1.90	57.94±2.15	0.01	0.112	0.911

PROM – Passive Range of Motion, SD- Standard Deviation, MD- Mean Deviation, HF – Hip flexion, HE- Hip Extension, HABD- Hip Abduction, HIR- Hip Internal Rotation, HER- Hip external Rotation, * - Significance level at p<0.05 (t-test performed)

Table 4: Comparison of Hip AROM between adolescents and adult female athletes

HIP AROM (Degrees)	Adolescent(n=231) Mean ± SD	Adult (n=286) Mean ± SD	MD	t value	p value*
Dominant HF	126.71±1.86	123.32±1.78	-3.38	-21.015	0.000
Dominant HE	22.90±1.35	24.22±0.91	1.32	13.256	0.000
Dominant HABD	43.42±1.15	44.40±0.76	0.98	11.507	0.000
Dominant HIR	44.42±1.47	45.24±1.41	0.82	6.440	0.000
Dominant HER	50.71±3.04	49.88±0.77	-.83	-4.442	0.000
Non-Dominant HF	124.47±1.98	121.84±1.78	-2.63	-15.910	0.000
Non-Dominant HE	22.65±0.90	23±0.79	.36	4.794	0.000
Non-Dominant HABD	40.80±1.37	40.44±0.95	-.36	-3.472	0.001
Non-Dominant HIR	41.85±1.27	42.98±1.08	1.13	10.908	0.000
Non-Dominant HER	50.39±2.15	44.86±1.00	-5.53	-38.618	0.000

AROM – Active Range of Motion, SD- Standard Deviation, MD- Mean Deviation, HF – Hip flexion, HE- Hip Extension, HABD- Hip Abduction, HIR- Hip Internal Rotation, HER- Hip external Rotation, * - Significance level at p<0.05 (t-test performed)

Table 5: Comparison of Hip PROM between adolescents and adult female athletes

HIP PROM (Degrees)	Adolescent(n=231) Mean ± SD	Adult (n=286) Mean ± SD	MD	t value	p value*
Dominant HF	130.99±1.55	128.44±2.21	-2.55	-14.848	0.000
Dominant HE	24.52±1.02	25.04±0.59	0.88	12.323	0.000
Dominant HABD	46.55±1.68	46.72±1.31	0.17	1.303	0.193
Dominant HIR	48.97±0.89	49.17±1.02	.20	2.372	0.018
Dominant HER	55.82±3.45	57.96±1.90	2.14	8.928	0.000
Non-Dominant HF	129.58±1.87	125.23±6.39	-4.35	-9.994	0.000
Non-Dominant HE	24.58±1.11	23.52±0.63	-1.06	-13.649	0.000
Non-Dominant HABD	46.61±1.69	46.63±1.32	.015	.111	0.912
Non-Dominant HIR	48.79±0.56	49.35±0.97	0.56	6.921	0.000
Non-Dominant HER	53.78±0.82	57.94±2.15	4.16	27.802	.000

PROM – Passive Range of Motion, SD- Standard Deviation, MD- Mean Deviation, HF – Hip flexion, HE- Hip Extension, HABD- Hip Abduction, HIR- Hip Internal Rotation, HER- Hip external Rotation, * - Significance level at p<0.05 (t-test performed)

3. RESULTS

Table 1 outlines the anthropometric and baseline descriptive characteristics of adult and adolescent athletes. The mean age of adult group (Age range:18-21years) and adolescent group (Age range: 15-17years) were 20.01± 0.89 and 16.13 ± 0.72 years respectively. The BMI distribution among both groups was found to be similar with the mean values of 21.23 ± 1.37 for adults and 21.39 ± 1.31 for adolescents. The representation of the study participants from a variety of sports specialties was found to be evenly distributed. The dominant leg for the lower extremity were most found to be right side for adolescent (90.9%) and adult (90.6%) female athletes. In table 2 the dominant leg showed a significantly higher AROM than the non-dominant leg in hip flexion, extension, abduction and internal rotation at p<0.05 in both groups of female athletes. On the other hand, the AROM for hip external rotation was not significantly different between dominant and non-dominant leg in 15-17 years age group (MD = 0.32, t = 1.417, p = 0.158) while in the 18-21 years of age group it was significant. The findings in table 3 revealed that adolescent group has no significant difference in the PROM between the legs for hip extension (MD = -0.07, t = -0.886, p = 0.377) and abduction (MD = -0.7, t = -0.466, p = 0.642). Similarly, adult group shows no significant difference in PROM between the legs for hip external rotation (MD = 0.01, t = 0.112, p = 0.911) while other motions in both groups were statistically significant at $p<0.05$. Table 4 presented the comparison between the two age groups for hip AROM where significant difference ($p<0.05$) was observed in all hip motions. Adolescents exhibited higher hip flexion (126.70 ± 1.86) compared to adults (123.32 ± 1.78) and on the other hand, adults had higher hip extension (22.90 ± 1.34) compared to adolescents (24.22 ± 0.91). Similar findings were documented for hip abduction, internal rotation, and external rotation, where adolescents showed higher AROM compared to adults. Like AROM, from table-5 significant differences were observed in hip PROM between the two age groups except for hip abduction (MD = 0.17, t = 1.303, p = 0.193). On comparison with adult group, adolescents demonstrated higher hip flexion, internal rotation, and external rotation, while the former showed higher hip extension.

4. DISCUSSION

This study aimed to establish normative values for both active and passive range of motion of the hip joint in female athletes, taking into consideration age and sports participation. In the Indian population, there has been a lack of well-documented reference values for hip range of motion among female athletes. While existing research has identified differences in range of motion based on gender and race, the athletic population, known for its higher physical fitness levels compared to sedentary individuals, has been lacking comprehensive reference values. Our study addresses this gap and provides valuable data that can be utilized in studies focusing on hip rehabilitation for female athletes. By offering insights into the expected range of motion in this specific population, our findings can contribute to more targeted and effective rehabilitation approaches for enhancing performance and reducing injury risks in female athletes.

This study is the first of its kind to report values of Active and passive ROM of Hip joint among adolescents and adult female sports players. **Anna S. Aminoff et al., (2020)** stated that hip ROM is affected by several parameters such as age, pain, degenerative changes, hip morphology, pelvic tilt and posture of lumbar spine. Hip ROM is usually measured in sitting, supine and prone positions.[9] Traditional method of measuring hip ROM is done using different methods including goniometer, inclinometer, potentiometer, photometer and x-ray.

The results of this study show that adult female athletes' hip joint AROM differs significantly between their dominant and non-dominant sides. These athletes may have more flexibility, strength, and neuromuscular control in their dominant hips based on the higher mean values of ROM that were found on the dominant side. The repetitive use and particular demands placed on the dominant side throughout their sporting activities may be responsible for these characteristics. The observed disparities between the dominant and non-dominant sides could be caused by several variables. For instance, during athletic competition, the dominant side performs dynamic motions and weight-bearing activities more frequently, increasing joint mobility and muscle adaptation. Additionally, the dominant side may experience greater muscle hypertrophy due to greater loading, further contributing to the differences in ROM[10].

The research's findings show the baseline Active Range of Motion (AROM) values for several hip movements in young female athletes. The AROM measurements for both the dominant and non-dominant sides are highlighted in the data, and it is noted that there are variations in the mean values of these two sides for each hip movement. One of the most important findings from the table is that the dominant side consistently has greater mean values for hip flexion with knee flexion, hip extension, hip abduction, hip internal rotation, and hip external rotation than the non-dominant side. This indicates that the dominant hip joint in these young female athletes moves more freely on average during these exercises. The dominance of one side over the other in terms of AROM is not uncommon.

Numerous reasons, such as neuromuscular control, muscle strength imbalances, and repetitive movement patterns from sports or daily activities are frequently blamed for the dominance of one side.[11] The more intense and repetitive movements an athlete uses, the greater flexibility and range of motion they eventually develop on their dominant side. AROM between the dominant and non-dominant sides was found to differ, and this finding may have effects on injury risk and sports performance.[12] Range of motion imbalances can force athletes to make compensatory movements, which could place additional strain on specific components and raise the risk of overuse injuries. Additionally, an imbalance in hip mobility may have a negative impact on athletic performance by altering movement patterns and the biomechanics of the lower limbs. [13]

Measurement of hip ROM in athletes is warranted as repetitive micro traumas associated with athletic activity causes reduction in Total Articular Range (TAR). This result is consistent with study conducted by **Manning et al., (2009)**.[14] Adolescents participating in strenuous sports activity or high levels of physical activity can cause repetitive strain to growth plate which may disrupt blood flow resulting in delayed growth plate closure. This acts as a contributing factor to abnormal hip morphology in players. The prevalence of cam morphology was found to be lower in females compared to male sports players.[9]

The observed differences in mean values of dominant and non-dominant hip ROM demonstrate the presence of side-to-side asymmetry, with higher values noted in the dominant hip in most directions. These findings align with previous research studies that have shown similar asymmetry patterns in hip ROM among individuals. The dominance of one side of the body can influence muscular strength, flexibility, and neural activation patterns, which may contribute to variations in ROM. The dominant side is often exposed to more stimuli and undergoes repetitive movements, resulting in enhanced muscle length and strength, thereby contributing to greater hip ROM.[15] These adaptations are likely attributed to functional demands placed on the dominant side during activities of daily living, sports, or occupation-specific tasks.[16] Several studies have supported our findings by reporting greater hip ROM on the dominant side. For instance, a study by Scott cheatham et al. investigated hip ROM in athletes and found similar results with higher dominant-side hip flexion, extension, abduction, internal rotation, and external rotation when compared to the non-dominant side. It is important to note that individual variations in hip dominance and specific movement patterns may influence the observed findings. Factors such as handedness, sport specificity, and previous injury history can contribute to variations in hip ROM between dominant and non-dominant sides. It would be beneficial for future studies to investigate these potential confounding factors to provide a comprehensive understanding of the mechanisms behind hip ROM asymmetry.[17]

Very few authors have reported normal hip ROM in adults in specific AROM rather than PROM. **Vivek Chadayammuri et al., (2016)** concluded that deficit in PROM strongly predicts femoral torsion and central acetabular version which helps in early detection of hip abnormalities as it was found to be higher in females compared to males.[18] Increase in flexion and internal rotation are related with femoral head asphericity and femoral ante torsion. Hence pre-season screening may be helpful in identifying athletes at risk for hip disorders and injuries.[19]

Kimberly (2021) concluded that reduced hip mobility can result in decreased ability to perform task specific FMS movements which implies that hip ROM is also essential for physical activities.[20] Hip flexion is a predictor for assessment of risk for injuries as hip flexion tightness shows altered running mechanics marked by early toe off, less flexion and extension angles as stated by **Augsberg et al., (2019)**[21]**.**There are also other studies supporting this evidence as abdominal strains have been reported in female tennis players with hip flexor tightness. To prevent strain stretching can be indicated as mentioned by **Simon W. Young (2014)** Hence measurement of hip range is essential and such data can be used during baseline assessment to prevent the risk of sport injuries.[22]

In the baseline Passive Range of Motion of Adult female athletes, The higher mean value of dominant hip flexion with knee flexion (128.44) compared to non-dominant hip flexion with knee flexion (125.23) indicates that individuals tend to have greater flexion capability on their dominant side. This finding is consistent with previous research that suggests the dominant side of the body often exhibits superior strength and coordination compared to the non-dominant side.[23]

Similarly, the mean value of dominant extension (25.40) was found to be higher than non-dominant extension (23.52). This suggests that individuals have a slightly greater extension range of motion on their dominant side. This finding aligns with previous studies that have reported asymmetry in joint range of motion between the dominant and non-dominant sides of the body.[24]

Regarding hip abduction, the mean value of dominant abduction (46.72) was slightly higher than non-dominant abduction (46.63), indicating a minimal difference in this particular movement between the two sides. This finding is in line with previous literature that has reported similar abduction capabilities on both sides of the body.[25]

A noteworthy difference was observed in the mean value of dominant internal rotation (49.17) compared to non-dominant internal rotation (49.35). This finding suggests that individuals may have slightly better internal rotation on their non-dominant side. However, this difference is minimal and may not have significant functional implications.[26]

Finally, dominant external rotation (57.96) was found to be higher than non-dominant external rotation (57.94), indicating a negligible difference between the two sides. This result aligns with previous studies that have reported symmetrical external rotation capabilities across both the dominant and non-dominant sides.[24] Limitation of hip rotation is a possible factor in aetiology of sports hernia**.**[27] Hip rotational ROM and abduction limitation were significantly associated with injuries such as groin pain, muscle strain and ACL injuries in soccer players and they are at higher risk of lower limb injuries.[28] **P. Kouyoumdjian et al., (2012)** concluded in his study that there is slight mean increase in external rotation compared to internal rotation.[29] Hence these data can be used as a screening tool to prevent on-field injuries.

5. CONCLUSION

In conclusion, the study provided a comprehensive insight in the differences between the dominant and non-dominant sides for hip range of motion. Greater motion in flexion, extension, and internal rotation indicates increased joint mobility and control in the dominant side more likely. These disparities could potentially influence functional tasks and athletic performance, as asymmetrical joint range of motion might affect movement mechanics and stability. Nevertheless, more comprehensive investigations are required to delve into the root causes of these variations and their potential significance in terms of injury prevention and the rehabilitation process.

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