"THE IMPACT OF QUADRICEPS AND HAMSTRINGS STRENGTH ASYMMETRY ON JUMP SHOOTING ACCURACY IN BASKETBALL PLAYER: AN OBSERVATIONAL STUDY"

By

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In partial fulfilment of the requirements for the degree of

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In

SPORTS PHYSIOTHERAPY

Under the guidance of

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ODISHA UNIVERSITY OF HEALTH SCIENCES

CERTIFICATE OF ACCEPTANCE

This is to certify that the dissertation entitled: THE IMPACT OF QUADRICEPS AND HAMSTRINGS STRENGTH ASYMMETRY ON JUMP SHOOTING ACCURACY IN BASKETBALL PLAYER, carried out by **Mr. Mangesh Tathe** , bearing University Registration Number 43MP435045, has been **evaluated and accepted** by me as an **Examiner / Evaluator**, appointed by the **Odisha University of Health Sciences, Bhubaneswar**, in partial fulfilment of the requirements for the award of the degree of **Master of Physiotherapy (MPT) in [Sports]**.

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I hereby declare that this dissertation/thesis entitled "**The impact of quadriceps and hamstrings strength asymmetry on jump shooting accuracy in basketball player**" is a bonafide and genuine research work carried out by me under the guidance of Dr.Deepak Kumar Pradhan , Assistant Professor, Abhinav Bindra Sports Medicine & Research Institute,Bhubaneswar,Odisha.

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This is to certify that the dissertation entitled **"THE IMPACT OF QUADRICEPS AND HAMSTRINGS STRENGTH ASYMMETRY ON JUMP SHOOTING ACCURACY IN BASKETBALL PLAYER** is a bonafide research work done by **Mangesh Tathe** under the guidance of **Dr. Deepak Kumar Pradhan (PT) Associate Professor, Abhinav Bindra Sports Medicine and Research Institute, Odisha**

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This is to certify that the dissertation entitled "**The impact of quadriceps and hamstrings strength asymmetry on jump shooting accuracy in basketball player**" is a bonafide research work done by Mangesh Tathe under the guidance of Dr.Deepak Kumar Pradhan , Assistant Professor, Abhinav Bindra Sports Medicine & Research Institute,Bhubaneswar,Odisha.

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At the very outset, I express my deepest gratitude to Dr. Apjit S. Bindra, chairman, Shree Abhinav A. Bindra, Founder, and Dr. Digpal Ranawat, Executive Director of Abhinav Bindra Sports Medicine and Research Institute, Bhubaneswar, Odisha for giving me this opportunity. I take this opportunity to convey my heartful gratitude to guide Dr. Deepak Kumar Pradhan ,Assistant Professor, Abhinav Bindra Sports Medicine and Research Institute, for his valuable suggestions rendered in giving shape and coherence to this endeavour. I express my sincere thanks to Dr. Chinmaya Kumar Patra, Principal, Dr. Deepak Kumar Pradhan, Assistant professor and other teaching and non-teaching staff for their support and help to make this dissertation successful. I also acknowledge with a deep sense of reverence, my gratitude towards my parents, and my Batchmates who have always supported me morally and mentally. I would like to take this time to every participant who participated in this study for their kind cooperation and vital information. And above all, I can't ignore the blessings of Lord Ganesh in completing this dissertation on time.

Date : Signature of the Candidate

Place:

LIST OF ABBREVIATIONS USED

M.P.T	**Master of Physiotherapy**
ACL	Anterior Cruciate Ligament
BJSAT	Basketball Jump Shooting Accuracy Test
H/Q Ratio	Hamstring-to-Quadriceps Ratio
CMJ	Countermovement Jump
CODS	Change of Direction Speed
GF	Gross Force
ACSM	American College of Sports Medicine
RPT	Registered Physical Therapist
1RM	One Repetition Maximum
SLCMJ	Single Leg Countermovement Jump

ABSTRACT

Background:. Lower limb strength asymmetry—particularly between the quadriceps and hamstrings—is a common issue among athletes and can negatively affect performance and increase injury risk. In basketball, jump shooting requires coordinated force production and stability, making muscular balance essential for accuracy and efficiency.

Objective:. To investigate the relationship between inter-limb strength asymmetry in the quadriceps and hamstrings and its impact on jump shooting accuracy in recreational male basketball players aged 18–30.

Method : Design: Cross-sectional observational study. Participants: 35 recreational male basketball players from Bhubaneswar with at least 4 months of consistent training. Measurements: Strength asymmetry assessed using an isometric weighing scale. Jump shooting accuracy evaluated via a standardized scoring system across multiple shooting trials. Analysis: Pearson's correlation used to determine relationships between muscle asymmetry and shooting accuracy.

Results :. Significant negative correlation between quadriceps asymmetry and shooting accuracy: $r(33) = -.894$, $p < .001$. Significant negative correlation between hamstring asymmetry and shooting accuracy: $r(33) = -.902$, $p < .001$. Hamstring asymmetry showed a slightly stronger impact on performance than quadriceps asymmetry

Interpretation: Muscle imbalances, especially in the hamstrings, disrupt biomechanical efficiency during jump shots. Hamstring asymmetry affects pelvic stability and knee control, leading to reduced shot precision. Even mild asymmetries .

Conclusion : Inter-limb asymmetry in quadriceps and hamstrings is strongly associated with reduced jump shooting accuracy in basketball players. Targeted strength training and

biomechanical re-education focusing on symmetry can enhance performance and reduce injury risk.

Keywords:. Basketball, Hamstring Asymmetry, Jump Shooting Accuracy, Injury Prevention, , Muscle Imbalance, Neuromuscular Control , Quadriceps Asymmetry, Recreational Athletes , Sports Performance , Strength Symmetry .

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INTRODUCTION

Basketball, as a dynamic and physically demanding sport, relies extensively on the capacity of athletes to execute rapid, multi-directional movements and to perform critical skills such as the jump shot. Among these, the jump shot is recognized for its technical complexity and pivotal role in game outcomes, demanding precise coordination between lower limb muscular strength, neuromuscular control, and biomechanical efficiency. With increased focus on performance optimization, researchers and practitioners have examined various factors that influence the effectiveness of jump shooting—particularly those related to lower limb strength and its inter-limb asymmetries.[1]

Lower limb musculature, specifically the quadriceps and hamstrings, are integral to explosive actions in basketball. These muscle groups do not merely contribute to jump height or power, but also play a vital role in controlling acceleration and deceleration, stabilizing the knee during flight and landing, and generating torque required for skill execution. The sequence and quality of their activation govern not only the height and trajectory of a jump but also the athlete's ability to maintain accuracy under game-specific stresses. Importantly, the balance between quadriceps and hamstrings is quantified by strength ratios and symmetry indices, which have emerged as key markers for both injury risk and performance assessment [3] [6]

Recent evidence highlights the prevalence and performance implications of lower limb strength asymmetry in team sports. Inter-limb asymmetry defined as the difference in strength or function between the dominant and non-dominant legs can result from a spectrum of influences, including genetic predisposition, habitual training biases, injury history, and uneven motor pattern development. Such asymmetries have been associated with altered movement mechanics, reduced stability, greater risk of musculoskeletal injuries, and diminished athletic performance effects that resonate profoundly in ballistic actions such as the jump shot. The quadriceps and hamstrings, as antagonists stabilizing and mobilizing the

knee, are particularly susceptible to these disparities, which may manifest in reduced control, compromised shooting form, and efficiency deficits during high-velocity play.[2]

Despite advances in sports science, there remains an incomplete understanding of the direct impact of quadriceps and hamstrings strength asymmetry on jump shooting accuracy, particularly in recreational basketball players. Most studies investigating lower limb asymmetry focus on elite athletes, with few extending their scope to amateur populations where strength imbalances may be less addressed and more prevalent. Moreover, prior research has frequently emphasized global performance metrics—such as vertical jump height—while the nuanced relationship between neuromuscular asymmetry and technical skills like shooting accuracy remains under-explored. This gap carries significant implications, as recreational athletes constitute a substantial segment of the basketball playing population and often lack access to targeted strength and conditioning resources.[4][5]

The rationale for this study is anchored in a growing body of literature that links lower limb strength asymmetry to both injury risk and reduced athletic performance. Basketball players, particularly those engaging in frequent jump shots, demand robust quadriceps strength for knee extension and explosive take-off, while hamstrings facilitate movement control, joint stabilization, and safe landings. Any imbalance in this functional relationship may negatively influence the mechanics of a jump shot by disrupting force transfer, timing, and motor coordination.[4]

Asymmetries between the quadriceps and hamstrings can be quantified using isometric or isokinetic dynamometry, allowing for precise measurement of peak torque and calculation of inter-limb ratios. The functional implications of these asymmetries extend beyond mere strength discrepancies; they influence kinetic chain efficiency during shooting and underpin the athlete's ability to adapt to varying match scenarios. For example, pronounced quadriceps dominance may accelerate knee extension but undermine eccentric control provided by the

hamstrings, increasing the risk of poor landings, missed shots, or acute injuries such as ACL tears. Conversely, excessive hamstring dominance may disrupt jump mechanics and reduce shooting power.[6]

The clinical and sporting relevance of assessing and addressing lower limb strength asymmetry is demonstrated by performance test protocols, such as the lower-limb symmetry index used for return-to-play decisions after ACL reconstruction. Most recommendations advocate for a symmetry index of 85–90% or higher between limbs to minimize injury risk, although values exceeding 10% asymmetry have been correlated with performance degradation and increased injury rates. Translating these clinical benchmarks into performance contexts, particularly the jump shot in basketball, offers an innovative approach for optimizing skill acquisition and injury prevention.[7]

Numerous studies have expanded the understanding of how lower limb strength asymmetries manifest in basketball and related sports. Ding et al. (2024) investigated longitudinal inter-limb asymmetries in joint strength among adolescent basketball players, reporting asymmetry scores ranging from 12.2% to 21.6%, with the ankle plantar flexor displaying the strongest negative association with countermovement jump performance; however, knee and hip joint asymmetries were also noted in elite cohorts. Esmaeili et al. (2022) further explored the bilateral asymmetry of the hamstring-to-quadriceps peak torque ratio at varying angular velocities in professional basketball players, concluding that assessment speed did not affect bilateral asymmetry. Kiba et al. (2025) extended these observations in healthy athletes, finding significant strength differences in hip flexors, hip abductors, and knee extensors, and emphasizing the necessity of considering leg dominance in performance assessments.[7][8]

Biomechanical analyses of the jump shot elucidate the crucial transitions and interdependencies between muscle groups. Okazaki et al. (2015) outlined the phases of the jump shot—preparation, ball elevation, stability, release, and follow-through—emphasizing

how segmental movement organization, mechanical efficiency, and control parameters influence both shot accuracy and consistency. Variables such as ball trajectory, release height, and velocity are not only determined by upper limb technique, but are fundamentally reliant on the foundation provided by lower limb muscular coordination, force output, and symmetry.

Additionally, strength and conditioning research has detailed normative values and common protocols for lower limb strength assessment in basketball. Faulks et al. (2024) identified the back squat and isometric mid-thigh pull as the most frequently used tests to evaluate lower limb strength in elite basketball players, but highlighted heterogeneity and the lack of standardization, especially regarding the assessment of inter-limb asymmetry and its impact on functional performance.[9]

Injury prevention research underscores the role of strength balance between quadriceps and hamstrings. Muscular imbalances are known predictors of ACL injury and other lower limb pathologies in basketball, with rehabilitation protocols often stressing restoration of symmetry and functional equivalence before return to sport. This consensus further highlights the need to adapt these principles for performance optimization in healthy, non-injured athletes. [10]

Despite abundant evidence linking lower limb symmetry to injury risk, there is limited research directly connecting quadriceps and hamstrings strength asymmetry to basketball-specific skill performance, especially jump shooting accuracy. Most existing studies focus on general strength profiles, return-to-play after injury, or global vertical jump ability, rather than on the nuanced skill of the jump shot and its dependence on precise neuromuscular control and force balance. Moreover, recreational basketball players represent a population with unique training backgrounds, skill development trajectories, and risk profiles, differentiating them from elite athletes and warranting targeted investigation. [6][11]

This study aims to fill these gaps by rigorously examining the correlation between quadriceps and hamstrings strength asymmetry and jump shooting accuracy in recreational basketball

players. By focusing on this population and skill, the research hopes to provide actionable insights for coaches, trainers, and athletes in designing individualized strength programs, refining shooting technique instruction, and promoting injury prevention strategies.

Quantifying the degree of strength asymmetry between the quadriceps and hamstrings in recreational basketball players. Measuring jump shooting accuracy using standardized performance protocols, Analyzing the relationship between lower limb strength asymmetry and jump shooting accuracy. Identifying potential thresholds of asymmetry that significantly impact performance and may warrant targeted intervention.

To address these aims, the study employs an observational design grounded in validated protocols and outcome measures. Strength asymmetry will be evaluated using portable, reliable dynamometry instruments, measuring peak isometric force output for quadriceps and hamstrings in both limbs. Asymmetry indices will be calculated, and categorized according to established standards. Jump shooting accuracy will be assessed using the Basketball Jump Shooting Accuracy Test (BJSAT), which objectively scores performance across multiple attempts and distances. Statistical analysis will include correlation coefficients, regression models, and group comparisons to elucidate associations and potential causality.

By elucidating the impact of lower limb strength asymmetry on a fundamental basketball skill, this research offers both theoretical and practical advancements for sports science. Its findings have the potential to inform targeted strength training, rehabilitation, and technical coaching interventions that not only enhance performance but also mitigate preventable risks among recreational athletes. Furthermore, the integration of robust measurement protocols and nuanced analysis serves as a guide for future research, promoting methodological rigor and translational relevance in sports medicine and athletic development.

In summary, assessing the impact of quadriceps and hamstrings strength asymmetry on jump shooting accuracy represents an innovative contribution to the intersection of sports

biomechanics, conditioning, and skill acquisition. By situating the study within the broader scientific context and addressing existing gaps, this introduction sets the stage for a comprehensive investigation with significant implications for player development, performance enhancement, and injury prevention in basketball.

AIM & OBJECTIVES

AIM

To examine the impact of quadriceps and hamstring inter-limb strength asymmetry of lower limb on jump shooting accuracy basketball players.

OBJECTIVES

A study to investigate correlation between quadriceps and hamstring strength asymmetry in lower limb with jump shooting accuracy in basketball player.

HYPOTHESES

Null Hypotheses:

There will be no significant correlation between quadriceps and hamstring strength asymmetry and jump shooting accuracy in recreational basketball players.

Alternative Hypotheses:

H^1 : There will be significant correlation between quadriceps and hamstring strength asymmetry and jump shooting accuracy in recreational basketball players**.**

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REVIEW OF LITERATURE

1) **Tom Faulks et.al (2024) conducted study on A Systematic Review of Lower Limb Strength Tests Used in Elite Basketball concluded that** Among elite basketball players, the back squat 1RM is the most used lower limb strength test. However, across studies, a large variability was evidenced, which suggests that lower limb testing procedures are heterogeneous in this population.

2) **Hamed Esmaeili ⇑, Ali Sharifi et.al (2022) conducted study on Bilateral asymmetry of hamstring to quadriceps isokinetic torque ratio in different angular velocities in professional basketball players concluded that** measurement velocity does not affect the bilateral asymmetry of the H:Q peak torque ratio of the dominant and non-dominant limbs. In clinical assessments of H:Q bilateral asymmetry, we suggest that physical trainer can assess bilateral asymmetry of H:Q with arbitrary angular velocities.

3) **Hiromu Kiba, RPT1, 2)*, Hiroichi Miaki, RPT, PhD3),(2025) et.al conducted study on Lower-limb asymmetry in healthy male athletes concluded that** this study found a significant difference between the dominant and non-dominant legs in the cross over hop test and 90° change of direction test, even when both lower limbs were healthy. This suggests that the decision to return to sports should consider not only the lower-limb symmetry index between the healthy and affected limbs but also whether the affected limb is the dominant or non-dominant leg.

4) **Victor H.A. Okazakia (2015)et.al conducted study on A review on the basketball jump shot concluded that** A comprehensive review of the literature on basketball shooting revealed a number of factors that influence shooting performance under a variety of conditions. The analysis of the trajectory of the ball during the basketball jump shot suggests that a higher release angle and release height in combination with a lower release velocity are the preferred combination when executing a successful jump shot. Using a higher release, angles provide a greater target area for the ball to pass through the basket's circumference area to produce a successful shot. In addition, higher release heights result in less horizontal distance travelled by the ball during flight and decreases the demand placed on the player to produce force and generate velocity to apply to the ball at release. Lower release velocities result in greater movement consistency and shooting accuracy.

5) **Ling Ding , Mengde Ly(2024) et.al conducted study on Associations Between Inter-Limb Asymmetry in Lower Limb Strength and Jump Performance in 14–15-Year-Old Basketball Players concluded that** inter-limb asymmetry of the ankle plantar flexor was negatively correlated with the CMJ, and it significantly impacted the jump performance of adolescent basketball players. Practitioners should pay attention to inter-limb asymmetry of the ankle to prevent injuries and enhance performance for adolescent basketball players.

6) **JiaWei chen (2023) et.al conducted study on A study on the effect of unilateral strength training intervention on lower limb asymmetry in college basketball players concluded that** (1) There is asymmetry of limbs in male participants of the China University Basketball League. The greatest differences in circumference indicators between the left and right sides of the upper and lower limbs were observed, while asymmetry in other indicators was not obvious. Asymmetry in strength indicators between the two sides of the limbs is mainly reflected in grip strength, dynamic balance ability and lower limb explosive strength.(2) 10 weeks of unilateral

strength training was effective in improving lower limb explosive strength, maximal strength and quick strength, as well as lower limb asymmetry in male participants of the China University Basketball League.(3) The reduction of lower limb asymmetry in male participants in the China University Basketball League can significantly improve explosive power and balance. These results confirm that unilateral strength training exercises can counteract/reduce the degree of asymmetry in the lower limb strength of young basketball players.

7) **Dongting Jiang, Zijian Liu(2023) et.al conducted study on Investigating the impact of inter-limb asymmetry in hamstring strength on jump, sprint, and strength performance in young athletes: comparing the role of gross force concluded that** for youth athletes, the GF of the hamstring is crucial for overall lower limb strength performance, and the importance of inter-limb symmetry of hamstring strength increases with the complexity of the task.

8) **OLUWATOYOSI B.A. OWOEYE, DAVIE MULENGA on et.al conducted study Normative Hamstrings and Quadriceps Isometric Strength Values and Hamstrings-Quadriceps Asymmetry in Healthy Collegiate Soccer and Basketball Players concluded that** first to provide normative values for peak isometric hamstrings and quadriceps strength using a low-cost hand-held dynamometer. The normative database from this study is valuable to coaches, sports medicine professionals, exercise scientists and other stakeholders to inform injury prevention, rehabilitation progression, return to play decisions and performance goals in collegiate soccer and basketball players

9) **Himawan Wismanadi1,Achmad Wi dodo et.al conducted study on 1 Effects of Hamstring Asymmetry on Agility and Leg Power in Badminton Players concluded that** Hamstring asymmetry significantly affects athletes' agility and leg power abilities, which impacts their performance in badminton matches that require changes in direction and explosive movements.

10) **Jon Dignazio ; Hannah Marchant (2025) et.al conducted study on Reliability and Validity of a Crane Scale for Isometric Knee and Shoulder Strength Assessment concluded that** A crane scale provides values similar to hand-held dynamometry but is not comparable to results from electromechanical dynamometry. The lack of concurrent validity between the crane scale and electromechanical dynamometry may be partially attributable to differences in stabilization and participant positioning.

11) **Dariusz Skalski ; Magdalena Prończuk (2024) et.al conducted study on The impact of asymmetry in lower limb muscle strength and power on straight-line running speed in female soccer players concluded that** the significant impact of lower limb mus-cle strength and power asymmetry on straight-line running speed in female soccer players. The findings underscore the necessity for balanced muscle development to enhance performance and reduce injury risk.

12) **Sime Versic 1 , Miran Pehar 2 (2021)) et.al conducted study on Bilateral Symmetry of Jumping and Agility in Professional Basketball Players:**

Differentiating Performance Levels and Playing Positions concluded that the bilateral symmetry of one-leg vertical jumps differentiates guards from forwards and centers. Additionally, the symmetry of jumping was found to be an indicator of performance level. Therefore, it is clear that the development of jumping capacities in basketball should be positionally specific. In other words, guards should develop both their dominant and non dominant side performance. A smaller difference between the dominant and non dominant sides will generate greater situational efficiency and consequently improve playing performance.

13) **Chris Bishop, Anthony Turner & Paul Read (2017): conducted study on Effects of inter-limb asymmetries on physical and sports performance: a systematic review concluded that** Single leg vertical and horizontal jumps have shown suitable sensitivity in detecting asymmetries; however, associations with CODS performance are varied. In contrast, asymmetries during single leg tests of reactive strength have shown stronger relationships with reductions in CODS performance, whereby faster performers displayed smaller inter-limb asymmetries.

14) **Marc Schiltz, MD; Ce´dric Lehance et.al conducted study on Explosive Strength Imbalances in Professional Basketball Players concluded that** The relative isokinetic and functional performances of professional basketball players were similar to those of junior players, with no dominant-side effect. A history of knee injury in the professional athlete, however, was reflected in bilateral isokinetic and functional asymmetries.

15) **Chris Bishop,1 Paul Read Et.Al Conducted Study On Vertical And Horizontal Asymmetries Are Related To Slower Sprinting And Jump Performance In Elite Youth Female Soccer Players Concluded That** the SLCMJ seems to be the most appropriate jump test for identifying between-limb differences with values ;12% showing negative associations with sprint times.

16) **Chris Bishop, Paul Read et.al conducted study on Effects of Interlimb Asymmetries on Acceleration and Change of Direction Speed: A Between-Sport Comparison of Professional Soccer and Cricket Athletes concluded that** between-limb asymmetries exhibit no association with speed and CODS in elite soccer players but are associated with reduced CODS in elite cricketers. Thus, the reduction of interlimb asymmetries may be of greater consideration when working with cricket vs. soccer athletes.

17) **David R. Bell, Jennifer L. Sanfilippo et.al conducted study on Lean Mass Asymmetry Influences Force and Power Asymmetry During Jumping in Collegiate Athletes concluded that** lean mass asymmetry in the lower extremity is at least partially responsible for asymmetries in force and power. However, a large percentage remains unexplained by lean mass asymmetry.

18) **Sime Versic , Miran Pehar (2021)conducted study on Bilateral Symmetry of Jumping and Agility in Professional Basketball Players: Differentiating Performance Levels and Playing Positions concluded that** the bilateral symmetry of one-leg vertical jumps differentiates guards from forwards and centers. Additionally, the symmetry of jumping was found to be an indicator of performance level. Therefore, it is clear that the development of jumping capacities in basketball should

be positionally specific. In other words, guards should develop both their dominant and non-dominant side performance. A smaller difference between the dominant and non-dominant sides will generate greater situational efficiency and consequently improve playing performance

19) **Brenton J. Boddington, Ashley J. Cripps (2019) gave The validity and reliability of the Basketball Jump Shooting Accuracy Test concluded that** The BJSAT is a reliable jump shooting accuracy test sensitive to shooting distance with players showing greater accuracy from two-point than three-point shots. In contrast, the BJSAT identified trivial differences in jump shooting accuracy of players competing at various, but relatively homogeneous, playing standards explaining the construct validity of the test. The BJSAT exhibited acceptable relative reliability between multiple trials among basketball players of different playing levels. Consequently, practitioners can use the BJSAT in tracking jump shooting accuracy at progressive levels of a season for purposes like assessing skill technique or rehabilitation interventions. Absolute reliability of the BJSAT however was greater than the accepted benchmark thus practitioners are urged to track shooting accuracy performance of individual athlete in relation to other team members over a duration of time.

20) **Nicolas h. Hart1, sophia nimphius3 et.al conducted study on musculoskeletal asymmetry in football Athletes: a product of limb function over time concluded that** asymmetries were evident in athletes as a product of limb function over time. Chronic exposure to Routine high-impact gravitational loads afforded to the support limb preferentially improved bone mass and structure (cross-sectional area And cortex thickness) as potent contributors to bone strength relative to the high-magnitude muscular loads predominantly afforded to the Kicking limb.

21) **Koulla Parpa and Marcos Michaelides conducted study on Anterior-Posterior and Inter-Limb Lower Body Strength Asymmetry in Soccer, Basketball, Futsal, and Volleyball Players concluded that** There should be special attention to female soccer and volleyball players since practice and professional competition in soccer and volleyball can cause larger lower-limb asymmetries. The isokinetic parameters would serve as a useful tool for strength and conditioning intervention planning to eliminate or prevent those imbalances. Further unilateral and bilateral jumping testing is recommended for the confirmation of imbalance.

Sr. no	Authors (year)	Aim	Method	Findings	Insights
1	Tom Faulks et al. (2024)	Systematic review of lower limb strength tests in elite basketball[	Systematic review of strength-testing protocols in elite cohorts	Back squat 1RM most used; procedures heterogeneous across studies	Standardization is needed to relate asymmetry and performance across studies
2	Hamed Esmaeili, Ali Sharifi et al. (2022)	Assess bilateral H:Q isokinetic torque asymmetry at different velocities	Isokinetic testing across multiple angular velocities, dominant vs non-dominant comparison	Measurement velocity does not affect bilateral H:Q asymmetry	Asymmetry can be assessed at arbitrary velocities in applied settings
3	Hiromu Kiba, Hiroichi Miaki et al. (2025)	Evaluate lower-limb asymmetry in healthy male athletes	Cross-over hop and 90° COD tests with limb dominance considered	Significant dominant vs non-dominant differences despite healthy limbs	RTP should consider dominance in addition to symmetry index
4	Victor H. A. Okazaki et al. (2015)	Review determinants of basketball jump-shot performance	Narrative review of biomechanical/performance literature	Higher release angle/height with lower release velocity improve success	Lower-limb symmetry supports consistent kinematics for optimal release
5	Ling Ding, Mengde Lyu et al. (2024)	Link inter-limb strength asymmetry to jump performance in 14–15-year-olds	Cross-sectional correlations of joint-specific asymmetry (plantar flexors) with CMJ	Ankle plantar-flexor asymmetry negatively correlates with CMJ	Distal asymmetry at the ankle impacts jump preparation and performance .

6	JiaWei Chen et al. (2023) [1]	Test unilateral strength training effects on lower-limb asymmetry	10-week unilateral training with pre–post explosive, maximal, quick strength and balance tests	Asymmetry reduced; explosive power, maximal/quick strength, and balance improved	Targeted unilateral programming effectively corrects asymmetry and boosts performance
7	Dongting Jiang, Zijian Liu et al. (2023)	Examine hamstring asymmetry vs jump, sprint, strength; role of gross force	Performance testing with hamstring strength profiling and gross force analysis	Hamstring gross force is crucial; symmetry importance rises with task complexity	Complex coordinated tasks (e.g., shooting) are more sensitive to hamstring asymmetry
8	O. B. A. Owoeye, D. Muleng a et al.	Provide normative isometric H/Q strength values and asymmetry in collegiate soccer/basketball	Low-cost hand-held dynamometry to build normative database	Norms support prevention, rehab progression, RTP, and performance goals	Normative data contextualize asymmetry magnitudes when interpreting accuracy changes
9	Himawan Wismanadi, Achmad Widodo et al. (2025)	Assess effects of hamstring asymmetry on agility and leg power in badminton	Cross-sectional testing of hamstring asymmetry vs agility and leg power metrics	Hamstring asymmetry significantly lowers agility and leg power	Supports broader link between hamstring symmetry and explosive direction changes
10	Jon Dignazio, Hannah Marchant et al. (2025)	Evaluate reliability/validity of a crane scale for isometric knee/shoulder strength	Method comparison against hand-held and electromechanical dynamometry	Crane scale aligns with HHD but not with electromechanical dynamometry due to stabilization/positioning	Device and setup influence asymmetry estimates and performance correlations

11	Dariusz Skalski, Magdalena Prończuk et al. (2024)	Impact of lower-limb strength/power asymmetry on straight-line speed in female soccer	Field speed testing with strength/power asymmetry analyses	Asymmetry significantly impairs straight-line running speed	Reinforces asymmetry–performance links relevant to locomotor tasks in court sports
12	Sime Versic, Miran Pehar et al. (2021)	Differentiate performance levels/positions via bilateral symmetry of jumping and agility	One-leg jump and agility tests stratified by position and level	One-leg jump symmetry differentiates guards vs forwards/centers; indicates performance level	Position-specific development of both limbs is advised for basketball performance
13	Chris Bishop, Anthony Turner, Paul Read (2017)	Systematic review of inter-limb asymmetries' effects on physical/sport performance	Synthesis of asymmetry assessments vs CODS, jumps, reactive strength	Single-leg jumps detect asymmetries; reactive-strength asymmetry relates to CODS reductions	Test selection matters; reactive-strength asymmetry may be most informative for precision tasks
14	Marc Schiltz, Cédric Lehance et al. (year in doc)	Characterize explosive strength imbalances in professional basketball	Isokinetic and functional tests with knee-injury history considered	No dominant-side effect overall; prior knee injury reflected in bilateral asymmetries	Injury history is a key driver of asymmetry and should be screened
15	Chris Bishop, Paul Read et al. (year in doc)	Relate vertical/horizontal asymmetries to sprinting and jump in elite youth female soccer	Jump tests including SLCMJ with correlations to sprint times	SLCMJ best identifies between-limb differences; >12% differences associate with slower sprints	Thresholds near 10–12% may be meaningful for performance and skill precision

16	Chris Bishop, Paul Read et al. (year in doc)	Compare effects of interlimb asymmetries on acceleration and CODS in soccer vs cricket	Between-sport comparison of asymmetry vs speed/CODS	No association in elite soccer; asymmetry reduces CODS in elite cricket	Sport-task specificity moderates asymmetry effects; avoid overgeneralization to basketball
17	David R. Bell, Jennifer L. Sanfilippo et al. (2014)	Determine contribution of lean mass asymmetry to jump force/power asymmetry	Body composition with force/power asymmetry analysis during jumps	Lean mass asymmetry partly explains force/power asymmetry; large unexplained variance remains	Neural/coordination factors beyond morphology likely underpin performance asymmetries
18	Sime Versic, Miran Pehar (2021)	Duplicate: symmetry of jumping/agility by position/level in pro basketball	As above: one-leg jump and agility across positions and levels	Symmetry differentiates positions and indicates performance level	Confirms positional nuances for asymmetry management in basketball
19	Brenton J. Bodding ton, Ashley J. Cripps et al. (2019)	Establish validity and reliability of the BJSAT	Multi-trial reliability and construct validity across distances and playing standards	Reliable and distance-sensitive; trivial differences across homogeneous standards; best for individual tracking	BJSAT suits monitoring accuracy changes alongside symmetry interventions longitudinally
20	Nicolas H. Hart, Sophia Nimphius et al. (year in doc)	Describe musculoskeletal asymmetry as product of limb function over time in football	Morphofunctional comparisons of support vs kicking limbs under chronic loads	Support limb shows greater bone mass/structure; kicking limb higher muscular loads	Chronic task specialization drives asymmetry; training should counterbalance limb roles

21	Koulla Parpa, Marcos Michaelides (year in doc)	Evaluate A–P and inter-limb lower-body strength asymmetry across sports	Isokinetic parameters with recommendations for unilateral/bilateral jumping tests	Larger asymmetries in female soccer/volleyball; isokinetics useful for planning; more jump testing recommended	Confirms sport/sex-specific asymmetry risks; integrate isokinetic and jumping tests in screening

METHODOLOGY

- **STUDY POPULATION:** RECREATIONAL BASKETBALL PLAYERS
- **STUDY SETTING:** LOCAL BASKETBALL CLUBS IN BHUBNESHWAR
- **SAMPLING DESIGN:** RANDOM SAMPLING DESIGN
- **SAMPLING CRITERIA:**

INCLUSION:

- Male basketball players aged 18–30 years were included.
- The players having at least 4 months of continuous basketball training and match play were included.
- Players who didn't have any musculoskeletal injuries in the past 4 months were included.
- The players not having any upper or lower limb injuries before 4 months of the study were included.
- Currently free from medical conditions affecting participation.
- Recreational status of players were assessed based on ACSM guidelines for physical activity.
- Those players engaged in regular moderate/vigorous activity that met ACSM minimum recommendations were included.

EXCLUSION:

- Lack of Informed Consent: Exclude participants who had not provided informed consent to participate in the study. Ethical guidelines require informed consent to protect participants' rights and privacy.
- Pre-existing Medical Conditions: Exclude players with pre-existing medical conditions or injuries that could significantly impact their

fitness parameters. For instance, individuals with chronic illnesses, cardiovascular diseases, or musculoskeletal disorders may distort the results.

- Players with severe injuries that significantly impact their ability to participate in fitness assessments.

- **SAMPLE SIZE:** 35
- **DURATION:** 1 Year
- **MATERIALS USED:**

1. Stopwatch
2. Pen, paper
3. Isometric weighing scale machine .
4. Marking cones.
5. Performance recording sheet

- **Outcome Measures: weighing scale machine**

-The strength asymmetry will be measured using an -The outcome measure in this study is jump shooting accuracy in basketball players.

- **INSTRUMENTS USED FOR OUTCOME MEASURES**

- **weighing scale machine** .

PROCEDURE

Ethical Clearance: Before commencing the study, ethical clearance was obtained to ensure that the research adheres to ethical standards and protects the rights of participants. Sample Selection: Participants were screened based on predefined inclusion and exclusion criteria. This ensured that only suitable candidates were included in the study. Informed Consent: After the sample selection, the procedure was explained to all participants. Informed consent was obtained from each participant, ensuring they understand the study's purpose, procedures, and any potential risks involved. Demographic Data Collection: Basic demographic data of the participants was collected to provide context for the study findings. Warm-Up: A standardized warm-up of 10 minutes was provided to all participants to prepare them for the strength and performance assessments. Strength Assessment: The strength asymmetry between the two limbs were measured using weighing scale machine. This tool was provide objective data on the strength of the quadriceps and hamstrings. Quadriceps Measurement: Participants were seated or lying down in a comfortable position, with the knee joint positioned at approximately 90 degrees to maintain consistency across measurements. They were instructed to apply maximal force against the dynamometer while extending the knee. The peak force generated by the quadriceps muscle was recorded for both the right and left limbs. Hamstring Measurement: Participants were instructed to exert maximal force against the dynamometer while flexing the knee. The peak force output from the hamstring muscle was documented for both limbs. Multiple trials (typically 2–3) were conducted for each muscle group to ensure reliability and accuracy of the measurements. Asymmetry Calculation: Muscle strength asymmetry was calculated by comparing the quadriceps and hamstring strength values between the two limbs. This was expressed either as a percentage difference or a strength ratio.

Jump Shooting Accuracy Test Test Objective - Participants completed a jump shooting accuracy test to assess their performance in jump shots—an essential basketball skill. Test Setup - Shooting locations on the court were predetermined, including varying distances such as two-point and three-point shot positions. Two assessors were assigned: one to oversee the procedure and another to record scores for each attempt. Scoring System – The scoring system was explained to all participants. For the BJSAT, scores typically ranged from 0 to 3 per shot, depending on accuracy and distance. Clear criteria were provided for scoring, including whether the shot was successful, its quality, and the distance from the basket. Test Procedure – Each athlete attempted a series of jump shots (usually eight) from the designated locations. Assessors scored each shot immediately after the attempt and recorded the corresponding value. Recording Scores - Total scores were calculated for each athlete based on the cumulative points across all shot attempts. Mean scores were determined for each trial and across multiple trials to track overall shooting accuracy.

RESULTS

Male Basketball player aged between 18 to 30 participated in this study after their written consent had been submitted. Data collection was done. Descriptive statistics were analysed for the participants. Data was then tested for Normality using the Shapiro-Wilk test. As the data was parametric, the correlation between quadriceps muscle asymmetry and overall shooting accuracy, and hamstring muscle asymmetry and shooting accuracy was calculated by Pearson's correlation.

The mean age of the participants has been found to be 24.23 ± 2.8

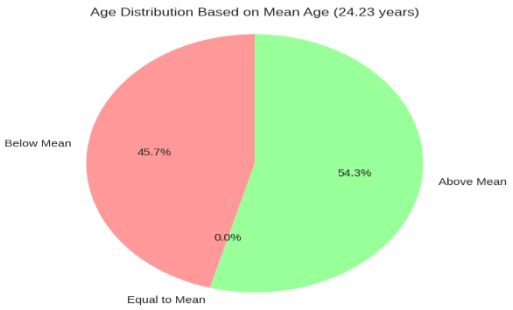


Figure 1shows mean age distribution

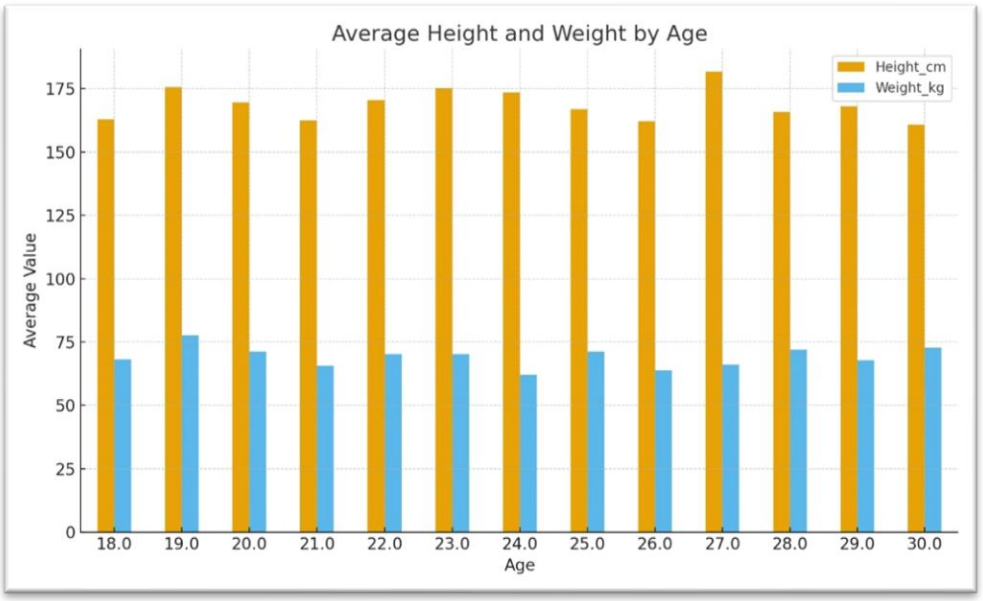


Figure 2 shows average height and weight

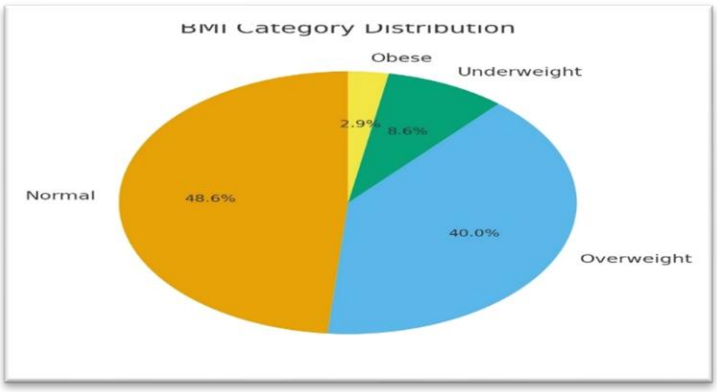
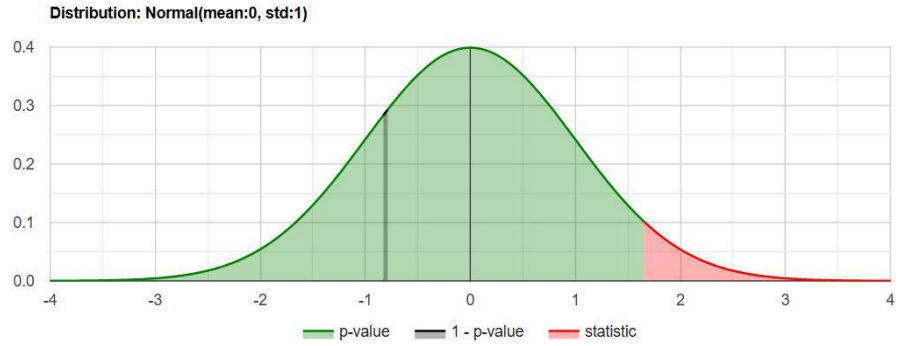
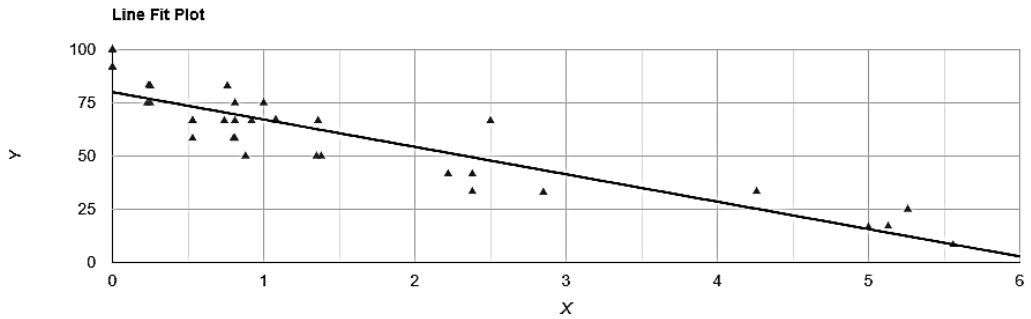


Figure 3 shows BMI category distribution

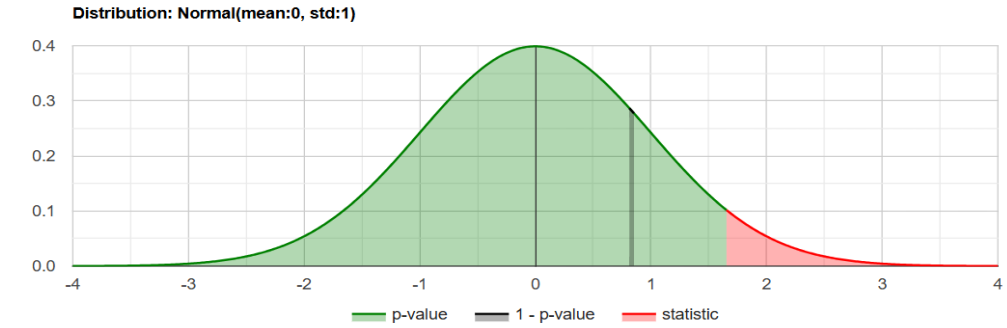
Quadriceps muscle asymmetry and overall shooting accuracy



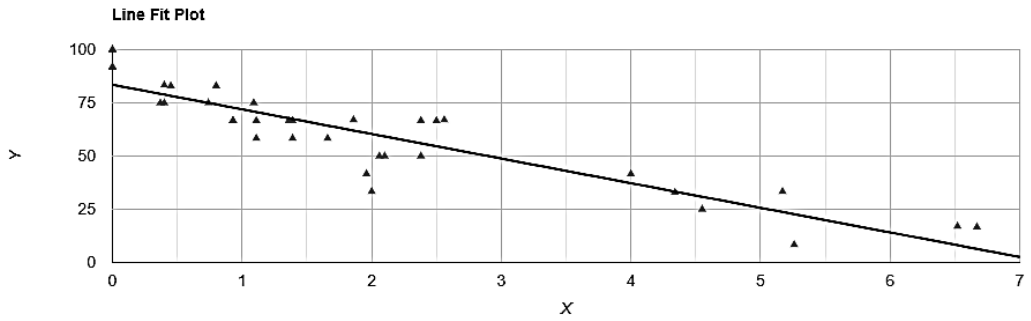
Results of the pearson correlation indicated that there is a significant large negative relationship between Quadriceps muscle asymmetry and overall shooting accuracy, ($r(33) = .894$, $p < .001$).



Hamstring muscle asymmetry and shooting accuracy



Results of the pearson correlation indicated that there is a significant large negative relationship between Hamstring muscle asymmetry and shooting accuracy, ($r(33) = .902$, $p < .001$).



DISCUSSION

The present study investigated the relationship between inter-limb quadriceps and hamstring asymmetry and shooting accuracy, revealing strong negative associations for both muscle groups. Specifically, hamstring asymmetry exhibited a marginally stronger correlation with decrements in shooting performance ($r = –.902$, $p < .001$) compared to quadriceps asymmetry ($r = –.894$, $p < .001$). These findings underscore the functional importance of muscular balance in the lower extremities, while also suggesting that deficits in hamstring symmetry may exert a more pronounced effect on technical execution in shooting tasks.

The quadriceps play a primary role in knee extension, forceful deceleration, and stability during jump-landing and shot preparation. Asymmetric strength across quadriceps muscles can compromise stability in the support leg and reduce the accuracy of force transfer to the ball during shooting. Previous research in collegiate soccer and basketball players indicates that quadriceps imbalances are common, with normative quadriceps strength ranging between 4.21–5.48 N/kg depending on sex and sport, and with “substantial” hamstrings-to-quadriceps (H/Q) ratio imbalances (<0.6) reported in up to 44% of players. Such imbalances increase mechanical load asymmetry, which in turn may diminish the precision of technical skills requiring bilateral coordination, such as basketball or soccer shooting.(1)

In line with this, Owoeye et al. also highlighted that quadriceps-dominant imbalances not only predispose players to anterior cruciate ligament (ACL) injury but also compromise kinetic chain efficiency, thereby impairing performance outputs. In the context of shooting accuracy, reduced quadriceps symmetry could manifest as inconsistent stabilization of the plant leg, leading to variability in ball trajectory.(1)

Even though quadriceps asymmetry is important, the current study's stronger negative correlation with hamstring asymmetry raises the possibility that hamstrings are even more important for precise shooting. As hip extensors and knee flexors, the hamstrings serve as

vital support for deceleration, dynamic knee stabilization, and pelvic tilt control during shot execution.

The kinetic chain may not align precisely during the shot if hamstring strength asymmetries affect the coordination of hip extension and knee stabilization. In accordance to a 2025 study on badminton players, hamstring asymmetry of more than 10% had a significant negative impact on leg power and agility, with large effect sizes. These results are consistent with the current findings, indicating that even mild hamstring dysfunction can result in significant declines in. These findings mirror the present results, suggesting that even moderate imbalances in hamstring function can translate into meaningful decrements in complex motor tasks.(2)

Evidence from Skalski et al. (2024) emphasizes that lower limb asymmetries exceeding 8% negatively affect sport-specific tasks such as sprinting, jumping, and technical execution in soccer.(3) While the study focused on running speed, the underlying mechanism—disrupted force symmetry—extends to accuracy-dependent actions such as shooting. The fact that shooting involves rapid deceleration followed by coordinated explosive movement suggests that hamstring deficits may have a disproportionately large impact compared to quadriceps, as they are crucial for stabilizing the pelvis and knee before ball contact.(3)

The slightly greater effect of hamstring asymmetry compared to quadriceps asymmetry may be explained biomechanically. During a shot, the quadriceps are heavily involved in concentric extension, but the hamstrings provide eccentric control and joint stability, ensuring accurate alignment of the trunk and lower limb. Without sufficient hamstring symmetry, the ability to modulate pelvic positioning and knee mechanics diminishes, leading to greater variability in shot accuracy.

This aligns with Bishop et al. (2018), who noted that inter-limb asymmetries—particularly in stabilizing muscles—can impair both performance and injury resilience, with effects most

pronounced in tasks requiring precise intersegmental coordination.Our findings expand this perspective by showing that even small differences in hamstring strength symmetry can substantially reduce accuracy in shooting tasks.

From an applied perspective, muscle asymmetry not only affects performance but also injury risk. Owoeye et al. (2024) demonstrated that athletes with significant hamstring-quadriceps imbalances are at greater risk for ACL injuries.(1) Similarly, Skalski et al. (2024) reported that asymmetries above 15% significantly increase injury incidence in female soccer players. (3) While our study did not directly assess injury outcomes, the strong correlations between asymmetry and performance reinforce the notion that reducing muscular imbalances is critical not only for accuracy but also for athlete longevity. Also, research on youth athletes showed that hamstring asymmetry had a greater impact on sprint performance compared to gross force, while both asymmetry and overall force equally influenced jump performance (5). Shooting in sports often involves sprinting and jumping—movements that require fine control of limb symmetry. Thus, hamstring asymmetry likely disrupts motor coordination across multiple performance domains relevant to shooting accuracy.(5)

The relationship between lower limb mechanics and shooting has been well-documented in basketball and soccer. Recent validation studies of jump shooting tests emphasize that consistency in lower limb alignment and strength is central to accuracy outcomes . Hamstring asymmetry may reduce the reproducibility of jump height and trunk alignment, thereby diminishing shooting accuracy, while quadriceps asymmetry may lead to inconsistent power generation during take-off.(1) (3) The present findings corroborate these biomechanical pathways by demonstrating strong statistical associations between asymmetry and shooting precision.The current research has significant practical ramifications for athletes' coaches, sport scientists, and clinicians. Performance testing batteries should incorporate routine screening for inter-limb strength asymmetry, especially in the quadriceps and hamstrings,

since even minor imbalances (less than 7%) have been demonstrated to impair shooting accuracy. Corrective techniques should be given top priority in strength and conditioning programs, with a focus on unilateral quadriceps strengthening to regain bilateral symmetry and eccentric hamstring training (such as Nordic hamstring exercises and single-leg Romanian deadlifts). Furthermore, by encouraging steady pelvic stability, trunk alignment, and coordinated force transfer through the lower limbs, technical coaching should strengthen biomechanical efficiency during shooting. Addressing asymmetry not only enhances accuracy in sport-specific tasks but also contributes to injury prevention, since imbalances have been associated with greater risk of ACL injuries and hamstring strains. Consequently, interventions that combine targeted strength training, biomechanical re-education, and individualized monitoring may optimize both performance and long-term athlete health.

CONCLUSION

The present study investigated the relationship between inter-limb quadriceps and hamstring asymmetry and shooting accuracy, revealing strong negative associations for both muscle groups. Specifically, hamstring asymmetry exhibited a marginally stronger correlation with decrements in shooting performance ($r = –.902$, $p < .001$) compared to quadriceps asymmetry ($r = –.894$, $p < .001$). These findings underscore the functional importance of muscular balance in the lower extremities, while also suggesting that deficits in hamstring symmetry may exert a more pronounced effect on technical execution in shooting tasks.

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LIMITATIONS

Several limitations warrant acknowledgment. First, the cross-sectional design precludes causal inference; while asymmetry correlates strongly with accuracy, longitudinal intervention studies are necessary to confirm whether correcting asymmetry directly improves shooting performance. Second, the normative thresholds of asymmetry associated with performance decline remain to be established. While previous literature cites 8–15% as critical cut-offs, our cohort exhibited much smaller asymmetries (generally <7%), yet significant relationships with accuracy still emerged. This suggests that even subtle imbalances may affect fine motor performance such as shooting. Future research should examine whether these thresholds differ across sports and competitive levels.

FUTURE SCOPE

Conduct longitudinal intervention studies to test if targeted strength-symmetry training improves shooting accuracy and reduces injuries. Assess asymmetry effects across diverse groups (female, youth, amateur to professional) to identify demographic-specific thresholds. Use 3D motion capture and EMG to analyze dynamic imbalances and their impact on shooting mechanics. Establish quantitative asymmetry cut-offs linked to performance decline and injury risk through prospective tracking. Develop wearable sensor–based monitoring and sport-specific rehab protocols incorporating symmetry criteria for return-to-play.

SUMMARY

In summary, this study demonstrates that both quadriceps and hamstring asymmetry are strongly and negatively associated with shooting accuracy, with hamstring asymmetry exerting a marginally greater effect. These results highlight the importance of muscular balance in the lower limbs, not only for injury prevention but also for optimizing technical execution in sport-specific tasks. By integrating strength symmetry assessments into regular monitoring and implementing corrective interventions, practitioners can enhance both performance and resilience in athletes.

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ANNEXURE

ANNEXURE- 1

INFORMED CONSENT

Informed Consent form to participate in a clinical trial

Study Title: The impact of quadriceps and hamstrings strength asymmetry on jump shooting accuracy in basketball player: An observational study

Study Number: _____

Subject‘s Name: _____

Date of Birth / Age: _____

Address of the Subject_____

Qualification _____

Occupation: _____

Signature of participant:

(i) I confirm that I have read and understood the information sheet dated _____for the above study and have had the opportunity to ask questions.

(ii) I understand that my participation in the study is voluntary and that I am free to withdraw at any time, without giving any reason.

(iii) I agree not to restrict the use of any data or results that arise from this study provided such a use is only for scientific purposes.

(iv) I agree to take part in the above study.

Signature of the Participant

_____

Date: _____/ ____/ _____

Signatory‘s Name: _____

Date:

Signature of the Investigator:

Study Investigator‘s Name: _____

Signature of the Witness: _____

Date: _____/ _____/ _____

Name of the Witness: _____

*Copy of the Patient Information Sheet and duly filled Informed Consent Form shall be handled over to the subject or his/her attendant.

Strength & Performance Assessment Form

Participant Details:

- Name: _____
- Age: _____
- Gender: _____
- Basketball Experience (months/years): _____
- Injury History (Last 4 months): _____

- Contact Number: _____
- Email: _____

Section 1: Inclusion & Consent

- ☐ Informed consent obtained
- ☐ Participant meets inclusion criteria
- ☐ No exclusion factors present

Consent Signature: _____ Date: _____

Section 2: Demographic Data

Data Point	**Response**
Age	_____
Gender	_____
Duration of basketball play	_____ months/years
Weekly training frequency	_____ times/week

Section 3: Strength Assessment

Preparation:

- Participant seated or lying comfortably with knees at ~90°.
- Maximal effort exerted against dynamometer.

Quadriceps Strength Test:

Limb	Peak Force (N or kg)	Notes
Right Quadriceps	_____	
Left Quadriceps	_____	

Hamstring Strength Test:

Limb	Peak Force (N or kg)	Notes
Right Hamstring	_____	
Left Hamstring	_____	

Calculations:

- **Inter-limb quadriceps asymmetry [%]:**

  Average of bothRight−Left×100

- **Inter-limb hamstring asymmetry [%]:**

  Average of bothRight−Left×100

Section 4: Jump Shooting Accuracy Test

Procedure:

- Warm-up for 10 minutes.
- Perform **x** jump shots from designated spots (specify positions).
- Record number of successful shots out of total attempts.

Shooting Spot	Attempts	Successful Shots	Success Rate (%)
Spot 1	_____	_____	_____%
Spot 2	_____	_____	_____%
(Add more as needed)			

Overall Shooting Accuracy: _____%

Section 5: Observations & Notes

- Participant's technique and movement quality:
- ---
- Participant fatigue or discomfort:
- ---
- Additional comments:
- ---

Section 6: Ethical & Safety Checks

- ☐ No physical risks observed
- ☐ Medical professional present if needed

Assessment Conducted By:

Name: _____ Signature: _____ Date: _____

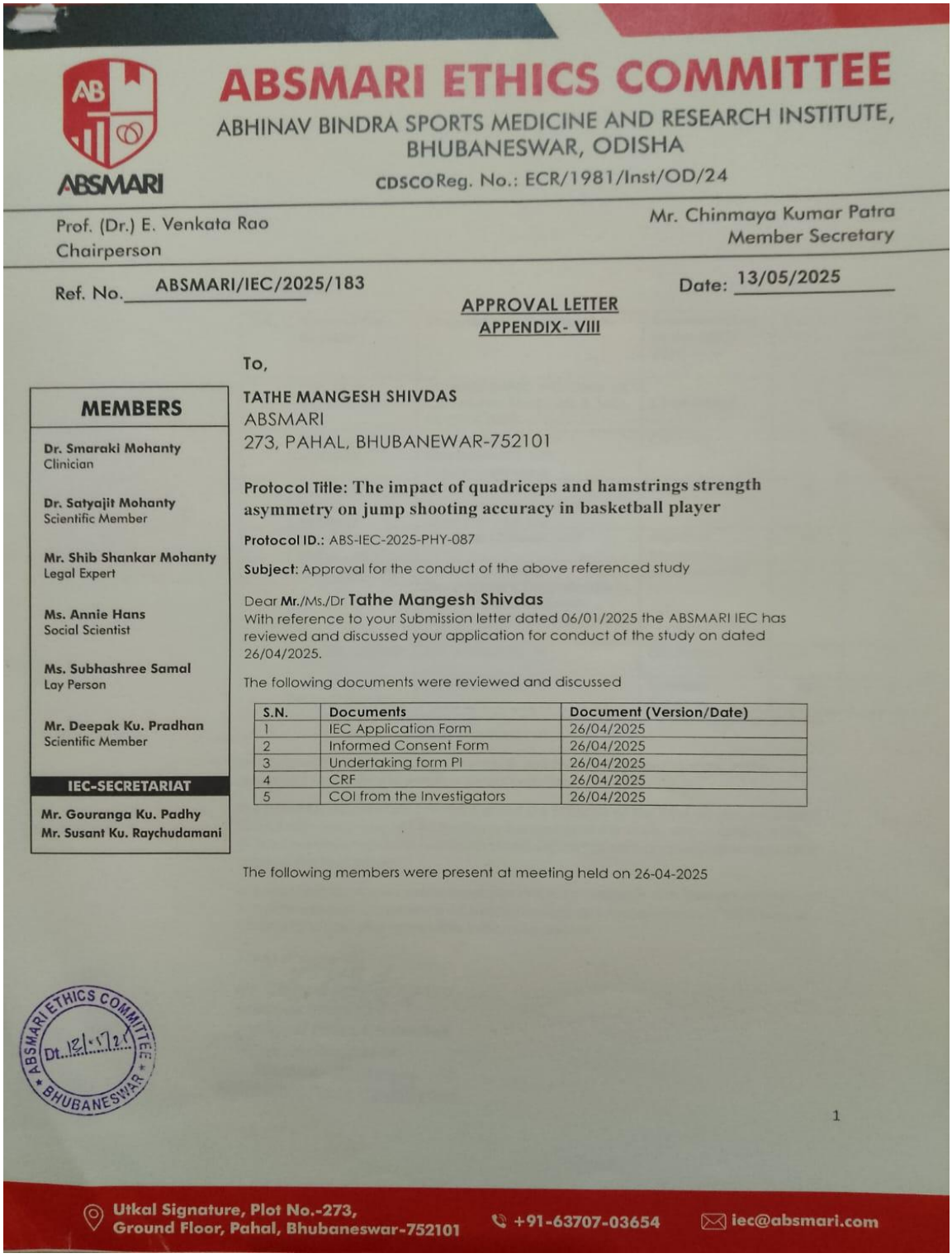
Participant Information

Name of Athlete	
Age	
Gender	☐ Male ☐ Female
Weight	
Height	
Dominant Hand	☐ Right ☐ Left
Playing experience	
Date	
Trial Number	☐ Trial 1 ☐ Trial 2 ☐Trial 3
Test Administrator	

Warm-Up Details

Warm-Up Type	Duration	Completed (✓)
Dynamic Warm-Up	15 min	☐
Hitting Warm-Up	5 min	

ANNEXURE -2



ABSMARI ETHICS COMMITTEE

ABHINAV BINDRA SPORTS MEDICINE AND RESEARCH INSTITUTE, BHUBANESWAR, ODISHA

CDSCO Reg. No.: ECR/1981/Inst/OD/24

Prof. (Dr.) E. Venkata Rao
Chairperson

Mr. Chinmaya Kumar Patra
Member Secretary

Ref. No. ABSMARI/IEC/2025/183

Date: 13/05/2025

APPROVAL LETTER
APPENDIX- VIII

To,

TATHE MANGESH SHIVDAS
ABSMARI
273, PAHAL, BHUBANEWAR-752101

MEMBERS

Dr. Smaraki Mohanty
Clinician

Dr. Satyajit Mohanty
Scientific Member

Mr. Shib Shankar Mohanty
Legal Expert

Ms. Annie Hans
Social Scientist

Ms. Subhashree Samal
Lay Person

Mr. Deepak Ku. Pradhan
Scientific Member

IEC-SECRETARIAT

Mr. Gouranga Ku. Padhy
Mr. Susant Ku. Raychudamani

Protocol Title: The impact of quadriceps and hamstrings strength asymmetry on jump shooting accuracy in basketball player

Protocol ID.: ABS-IEC-2025-PHY-087

Subject: Approval for the conduct of the above referenced study

Dear **Mr.**/Ms./Dr **Tathe Mangesh Shivdas**
With reference to your Submission letter dated 06/01/2025 the ABSMARI IEC has reviewed and discussed your application for conduct of the study on dated 26/04/2025.

The following documents were reviewed and discussed

S.N.	Documents	Document (Version/Date)
1	IEC Application Form	26/04/2025
2	Informed Consent Form	26/04/2025
3	Undertaking form PI	26/04/2025
4	CRF	26/04/2025
5	COI from the Investigators	26/04/2025

The following members were present at meeting held on 26-04-2025

ABSMARI ETHICS COMMITTEE Dt. 12/05/25 BHUBANESWAR

1

Utkal Signature, Plot No.-273, Ground Floor, Pahal, Bhubaneswar-752101 +91-63707-03654 iec@absmari.com

ANNEXURE - 3

FIG.8- ISOMETRIC HAMSTRING STRENGTH MEASUREMENT

FIG.9/ FIG.10 – BASKETBALL JUMP SHOOTING ACCURACY TEST

Participant	Age	Gender	Quadriceps strength test		Inter-limb quads assym	Hamstrings strength test		Inter-limb hams asymm	Shooting accuracy							Overall shootir
			Rt peak force(N	Lt peak force (N/kg)		Rt peak force (N	Lt peak force (N/kg)		Spot 1			Spot 2				
									Attempts	Successful shots	Success rate(%)	Attempts	Successful shots	Success rate(%)		
P1	27	MALE	393	390	0.76%	247	245	0.80%	6	5	83.33%	6	5	83.33%		83%
P2	25	MALE	373	371	0.53%	215	213	0.93%	6	4	66.60%	6	4	66.60%		66.66%
P3	22	MALE	360	355	1.38%	190	186	2.10%	6	3	50%	6	3	50.00%		50%
P4	29	MALE	370	367	0.81%	215	212	1.39%	6	3	50%	6	5	83.33%		66.66%
P5	25	MALE	425	424	0.23%	245	244	0.40%	6	4	66.66%	6	5	83.33%		75%
P6	26	MALE	430	430	0.00%	245	245	0.00%	6	6	100%	6	6	100%		100%
P7	28	MALE	460	460	0.00%	275	275	0.00%	6	5	83.33%	6	6	100.00%		92%
P8	19	MALE	370	367	0.81%	182	180	1.09%	6	5	83.33%	6	4	67%		75.00%
P9	22	MALE	370	366	1.08%	195	190	2.56%	6	4	66.66%	6	4	66.66%		67%
P10	26	MALE	404	403	0.24%	248	247	0.40%	6	5	83.33%	6	5	83.33%		83.33%
P11	22	MALE	366	361	1.36%	210	205	2.38%	6	4	66.66%	6	4	66.66%		66.66%
P12	25	MALE	372	370	0.53%	180	178	1.11%	6	4	66.66%	6	3	50%		58.33%
P13	28	MALE	405	402	0.74%	220	217	1.36%	6	5	83.33%	6	3	50%		66.66%
P14	22	MALE	374	371	0.80%	180	177	1.66%	6	4	66.66%	6	3	50%		58.33%
P15	27	MALE	386	385	0.25%	220	219	0.45%	6	5	83.33%	6	5	83.33%		83%
P16	26	MALE	390	390	0.00%	240	240	0.00%	6	6	100.00%	6	5	83.33%		91.66%
P17	20	MALE	325	322	0.92%	180	178	1.11%	6	4	66.66%	6	4	67%		66.66%
P18	23	MALE	340	337	0.88%	194	190	2.06%	6	4	66.66%	6	2	33.33%		50.00%
P19	24	MALE	400	400	0%	265	265	0.00%	6	6	100.00%	6	6	100%		100.00%
P20	25	MALE	370	367	0.81%	215	212	1.39%	6	3	50.00%	6	4	66.66%		58.33%
P21	21	MALE	400	398	1%	270	268	0.74%	6	4	66.66%	6	5	83.33%		75.00%
P22	26	MALE	370	366	1.08%	215	211	1.86%	6	4	67%	6	4	66.66%		67%
P23	23	MALE	400	399	0.25%	265	264	0.37%	6	5	83.33%	6	4	67%		75.00%
P24	20	MALE	372	370	0.53%	215	213	0.93%	6	4	66.66%	6	4	66.66%		66.66%
P25	26	MALE	370	365	1.35%	210	205	2.38%	6	3	50.00%	6	3	50.00%		50.00%
P26	27	MALE	420	410	2.38%	250	240	4%	6	3	50%	6	2	33.33%		41.60%
P27	25	MALE	390	370	5.13%	230	215	6.52%	6	1	16.66%	6	1	16.66%		17%
P28	24	MALE	400	390	2.50%	200	195	2.50%	6	3	50%	6	5	83.33%		66.60%
P29	26	MALE	350	340	2.85%	230	220	4.34%	6	2	33.33%	6	2	33.33%		33%
P30	20	MALE	380	360	5.26%	220	210	4.55%	6	1	17%	6	2	33%		25%
P31	27	MALE	470	450	4.26%	290	275	5.17%	6	2	33.33%	6	2	33.33%		33.33%
P32	23	MALE	360	340	5.56%	190	180	5.26%	6	0	0.00%	6	1	17%		8.33%
P33	28	MALE	420	410	2.38%	250	245	2%	6	2	33.33%	6	2	33%		33.33%
P34	22	MALE	400	380	5%	225	210	6.67%	6	1	16.66%	6	1	16.66%		16.66%
P35	19	MALE	450	440	2.22%	253	248	1.96%	6	3	50%	6	2	33.33%		41.66%

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