

**IMPACT OF HIGH AND LOW FUNCTIONAL MOVEMENT
SCREENING SCORES
ON KNEE FLEXION ANGLE AMONG RECREATIONAL KHO-
KHO PLAYERS: AN OBSERVATIONAL STUDY**

By

KALYANI MAHARANA

**Dissertation Submitted to the
Odisha University of Health Sciences, Bhubaneswar, Odisha**

**In Partial Fulfilment
Of the requirements for the degree of**

**MASTER OF PHYSIOTHERAPY (MPT)
In
SPORTS**

Under the Guidance of

**DR. CHINMAYA KUMAR PATRA (PT)
Principal, ABSMARI**

**Co- Guide
DR. SUNANDA BHOWMIK (PT)
Associate Professor**



**ABHINAV BINDRA SPORTS MEDICINE AND RESEARCH
INSTITUTE BHUBANESWAR, ODISHA –
2023-2025**



Odisha University of Health Sciences, Bhubaneswar, Odisha

DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation/thesis entitled **“IMPACT OF HIGH AND LOW FUNCTIONAL MOVEMENT SCREENING SCORES ON KNEE FLEXION ANGLE AMONG RECREATIONAL KHO-KHO PLAYERS: AN OBSERVATIONAL STUDY”** is a bonafide and genuine research work carried out by me under the guidance of **Dr. Chinmaya Kumar Patra**, Principal and Co- Guide **Dr. Sunanda Bhowmik**, Associate Professor, Abhinav Bindra Sports Medicine and Research Institute, Bhubaneswar, Odisha.

Date :

Signature

Place :

Kalyani Maharana

DECLARATION BY THE GUIDE

This is to certify that the dissertation entitled “**IMPACT OF HIGH AND LOW FUNCTIONAL MOVEMENT SCREENING SCORES ON KNEE FLEXION ANGLE AMONG RECREATIONAL KHO-KHO PLAYERS: AN OBSERVATIONAL STUDY**” is a bonafide research work done by **Kalyani Maharana** under my guidance in partial fulfilment of the requirement for the degree of **MPT- Master of Physiotherapy in sports speciality**.

Date :

Signature of the Guide

Place :

Dr. Chinmaya Kumar Patra (PT)

DECLARATION BY THE CO-GUIDE

This is to certify that the dissertation entitled “**IMPACT OF HIGH AND LOW FUNCTIONAL MOVEMENT SCREENING SCORES ON KNEE FLEXION ANGLE AMONG RECREATIONAL KHO-KHO PLAYERS: AN OBSERVATIONAL STUDY**” is a bonafide research work done by **Kalyani Maharana** under my guidance in partial fulfilment of the requirement for the degree of **MPT- Master of Physiotherapy in sports speciality**.

Date :

Signature of the Co-Guide

Place :

Dr. Sunanda Bhowmik (PT)

ENDORSEMENT BY THE HEAD OF THE DEPARTMENT

This is to certify that the dissertation entitled “**IMPACT OF HIGH AND LOW FUNCTIONAL MOVEMENT SCREENING SCORES ON KNEE FLEXION ANGLE AMONG RECREATIONAL KHO-KHO PLAYERS: AN OBSERVATIONAL STUDY**” is a bonafide research work done by **Kalyani Maharana** under the guidance of **Dr Chinmaya Kumar Patra (PT)**, Principal, and co-guide **Dr Sunanda Bhowmik (PT)**, Associate Professor, Abhinav Bindra Sports Medicine and Research Institute, Odisha, Bhubaneswar

Date:

Seal & Signature of the HOD

Place:

Name:

Name of the department

ENDORSEMENT BY THE PRINCIPAL

This is to certify that the dissertation entitled “**IMPACT OF HIGH AND LOW FUNCTIONAL MOVEMENT SCREENING SCORES ON KNEE FLEXION ANGLE AMONG RECREATIONAL KHO-KHO PLAYERS: AN OBSERVATIONAL STUDY**” is a bonafide and research work carried out by **Kalyani Maharana** under the guidance of **Dr. Chinmaya Kumar Patra (PT)**, Principal and Co - Guide **Dr. Sunanda Bhowmik (PT)**, Associate Professor, Abhinav Bindra Sports Medicine and Research Institute, Bhubaneswar, Odisha.

Date :

Seal & Signature of the Principal

Place :

Dr. Chinmaya Kumar Patra (PT)
Principal, ABSMARI

COPYRIGHT

DECLARATION BY THE CANDIDATE

I Kalyani Maharana of Abhinav Bindra Sports Medicine and Research Institute, Bhubaneswar, Odisha hereby declare that the Odisha University of Health Sciences and Abhinav Bindra Sports Medicine and Research Institute, Bhubaneswar, Odisha shall have the rights to preserve, use and disseminate this dissertation/ thesis in print or electronic format for academic/ research purpose.

Date :

Signature

Place :

Kalyani Maharana

© Odisha University of Health Sciences, Bhubaneswar, Odisha

**© Abhinav Bindra Sports Medicine and Research Institute, Bhubaneswar,
Odisha**

ACKNOWLEDGEMENT

I extend my sincere gratitude and appreciation to Dr Apjit S. Bindra (Chairman), Mr Abhinav A Bindra, Founder and Dr Digpal Ranawat, Executive Director of Ahinav Bindra Sports Medicine and Research Institute.

I take this opportunity to convey my deepest gratitude to my dissertation guide, Dr. Chinmaya Kumar Patra, the Principal, Abhinav Bindra Sports Medicine and Research Institute, Bhubaneswar. Your encouragement and belief in my abilities have been a source of motivation and confidence.

And Co-guide Dr. Sunanda Bhowmik, Associate Professor, Abhinav Bindra Sports Medicine and Research Institute, Bhubaneswar. Your unwavering support, expert guidance, and insightful feedback have been instrumental in shaping this research. Your dedication to excellence in academia has inspired me to strive for higher goals in my academic pursuits.

Furthermore, I would like to extend special thanks to Dr. Deepak Pradhan for his valuable assistance and support throughout this research. His expertise and constructive criticism have helped me refine my work and explore new dimensions in my study. I am also thankful to all the faculty members (a special thanks to Dr Priyadarshini Mishra, Dr Joydip Saha and Dr Gayatri Upasana Acharya, Dr Asifuzzaman) who have always supported me morally, mentally and academically.

I would like to express my heartfelt gratitude to my family and friends (special thanks Ms. Ananya, Mr. Chirag, Mr. Madhavan, Mr. Abhiram, Ms. Rojalin, Mr. Prince) for their unwavering encouragement, understanding, and love.

I would like to extend my heartfelt regards to Mr. Gouranga Kumar Padhy and team for helping and supporting us in every step.

And to the management and administration of Abhinav Bindra Sports Medicine and Research Institute, Bhubaneswar, and those who have supported and guided me throughout the journey of this dissertation. Without their valuable contributions, this work would not have been possible.

In conclusion, this dissertation stands as a testament to the collaborative efforts of the individuals mentioned above, and I am deeply grateful for their contributions to my academic success.

And above all, I can't ignore the blessings of LORD JAGGNATH whose has been a constant source of strength during my academic journey

Thank you.

Date :

Signature of the candidate

Place :

Kalyani Maharana

LIST OF ABBREVIATIONS USED

1. ABSMARI - Abhinav Bindra Sports Medicine and Research Institute
2. ACL- Anterior cruciate Ligament
3. AUC metrics- Area under curve
4. BMI- Body Mass Index
5. CI- Confidence Interval
6. df- difference
7. FMS- Functional Movement Screening
8. IEC- Institutional Ethical Committee
9. LESS – Landing Error Scoring System
10. Lt- Left
11. NCAA- National Colligate Athletic Association
12. PFPS- Patello femoral pain syndrome
13. ROC- Receiver operating characteristics
14. ROM- Range of Motion
15. Rt- Right
16. Sig- Significance
17. SPSS - Statistical Package for social science
18. SD - Standard Deviation

TABLE OF CONTENTS

Sr.no	Content	Page No
1	ABSTRACT	14
2	INTRODUCTION	16
3	NEED OF THE STUDY	29
4	REVIEW OF LITERATURE	35
5	AIM & OBJECTIVE OF THE STUDY	31
6	HYPOTHESES	32
7	MATERIAL & METHODOLOGY	48
8	PROCEDURE	53
9	STATISTICAL ANALYSIS	57
10	RESULTS	59
11	DISCUSSION	72
12	CONCLUSION	80
13	LIMITATIONS AND RECOMMENDATION FOR FUTURE STUDIES.	78
14	SUMMARY	82
15	REFERENCES	83
16	ANNEXURES	90

LIST OF TABLES

Sr. No	Table	Page No.
1	TABLE 1: Test for normality	60
2	TABLE 2: Spearman's Correlations Between Continuous Variables	61
3	TABLE 3: Table 3. Independent Samples t-test for Variables	65
4	TABLE 4: Mann-Whitney U Test for Gender Differences in FMS Score	66
5	Table 5. Chi-square Test of Association Between Gender and Risk Group	67
6	Table 6: Correlation of FMS Score and Rt knee flexion angle	68
7	Table 7: Correlation of FMS score and Lt knee flexion Angle	69

LIST OF FIGURES AND GRAPHS

Sr. No.	Graphs \ Figures	Page No.
Figure 1	Single leg squat for female athlete	55
Figure 2	Single leg squat for male athlete	55
Figure 3	Graph 1: Normality plot of age	61
Figure 4	Graph 2: Normality plot of height	61
Figure 5	Graph 3 : Normality plot of weight	62
Figure 6	Graph 4: Normality plot of FMS	62
Figure 7	Graph 5: Normality plot of Rt knee flexion	63
Figure 8	Graph 6: Normality plot of Lt knee flexion	63
Figure 9	Graph 7: Normality plot of gender	64

ABSTRACT

Title: IMPACT OF HIGH AND LOW FUNCTIONAL MOVEMENT SCREENING SCORES ON KNEE FLEXION ANGLE AMONG RECREATIONAL KHO-KHO PLAYERS: AN OBSERVATIONAL STUDY

Background: Kho-Kho is a multidirectional, agility-intensive sport whose crouching, sprinting and rapid-change movements place high biomechanical demand on the knee joint. The Functional Movement Screen (FMS) is a practical, field-based tool designed to assess movement quality and identify movement dysfunctions that may increase injury risk. However, the relationship between FMS composite scores and knee flexion biomechanics in Kho-Kho players is not well established in recreational kho-kho players.

Objectives: To examine the association between high and low FMS scores and knee flexion angles among recreational Kho-Kho players.

Methods: An observational correlation study recruited 87 recreational Kho-Kho players. Participants completed the standard seven-component FMS. Kinematic analysis of right and left knee flexion angles was measured from video recordings and analyzed using 2D software Kinovea video-analysis.

Results: The sample (n=87) demonstrated a non-normal distribution for FMS scores. A moderate, statistically significant positive correlation was observed between FMS composite score and left knee peak flexion ($\rho=0.611$, $p<0.001$). No significant correlation was found between FMS score and right knee peak flexion. Group comparisons between high- and low-risk FMS categories showed no significant

differences in anthropometrics or knee flexion angles. Gender did not significantly influence FMS classification.

Conclusion: Higher FMS composite scores were associated with greater left knee flexion among recreational Kho-Kho players, suggesting that superior functional movement proficiency relates to greater knee joint flexion during sport-relevant tasks. FMS may be a useful component of multifactorial screening to guide corrective mobility and neuromuscular training, although longitudinal research including strength and neuromuscular measures is needed to establish causal links and injury-prevention strategies as well.

Keywords: Athletic Injuries, Athletic Performance, Biomechanical Phenomena, Cross-Sectional Studies, Exercise, Humans, Knee Injuries, Knee Joint, Motor Skills, Physical Fitness, Range of Motion, Articular, Sports, Sports Medicine

INTRODUCTION

Kho-Kho is one of India's most traditional and popular indigenous sports, played on a rectangular field with two teams chasing and tagging opponents. Known for its speed, agility, and strategic movement, the game emphasizes teamwork, reflexes, and rapid decision-making. Its unique crouching and sprinting patterns place significant physical demands on players, particularly on the lower limbs, making it both a culturally rich and athletically demanding sport. Kho-Kho, a traditional tag sport indigenous to South Asia, requires athletes to execute rapid changes of direction, frequent crouching, sudden accelerations, decelerations and multi-directional sprints movements that place considerable biomechanical load on the lower extremities, particularly the knee joint. At the recreational level, players usually don't get formal training in how to move, which can lead to ineffective movement patterns that hurt performance and cause injuries to the musculoskeletal system. So, looking at the quality of functional movement in Kho Kho athletes is useful for both preventing injuries and improving performance.

Functional Movement Screen (FMS™) gives you a structured way to test how well you move. There are seven standardized movement tests: deep squat, hurdle step, in-line lunge, shoulder mobility, active straight-leg raise, trunk stability push-up, and rotary stability. Each test is scored from 0 to 3. The composite score (0–21) shows how well a person can move overall; higher scores mean better movement quality [1]. Its conceptual basis rests on the premise that movement compensations, asymmetries, or neuromuscular deficits, when unchecked, can predispose individuals to injury by compromising kinetic chain integrity.

Recent meta-analytical evidence underscores FMS's reliability and predictive relevance. In a systematic review, Chūnna et al. reported excellent inter-rater and intra-rater reliability (ICC \approx 0.81) and demonstrated that individuals scoring \leq 14 had

2.74 times higher odds of sustaining musculoskeletal injury compared to those with better scores (95% CI 1.70–4.43) [2]. Complementarily, another meta-analysis encompassing over 2,200 participants found that athletes classified as “high risk” (FMS <13–14) had a relative risk (RR) of 1.51 (95% CI 1.35–1.69) of injury compared to low-risk individuals, though the authors noted the overall evidence quality remained low [3].

However, the predictive accuracy of FMS remains debated. A broad literature review flagged high specificity but low sensitivity, suggesting FMS more reliably identifies those unlikely to be injured rather than accurately predicting those who will [4]. Indeed, sensitivity values fluctuated widely across studies from a mere 26% to as high as 68% while specificity ranged from 38% to 96%, and area under the curve (AUC) benchmarks oscillated between 0.42 and 0.68 [5]. Such variability underscores potential limitations in applying FMS as a universal risk prediction tool.

Despite these nuances, FMS retains substantial practical appeal due to its cost-effectiveness, portability, and ease of administration, making it an attractive option for coaches, trainers, and rehabilitation professionals. Moreover, structured training interventions such as resistance training, neuromuscular and core stability exercises have demonstrated moderate-certainty improvements in FMS scores (mean differences ranging from 1.74 to 2.89; $P < 0.001$), reinforcing both the tool’s responsiveness and potential utility in movement remediation [6].

In Kho-Kho, the frequent low-level postures and agility-intensive demands amplify the importance of movement proficiency, especially at the knee joint a pivotal locus for absorbing ground reaction forces and maintaining dynamic stability. Yet, to date, there

appears to be no biomechanical research linking FMS scores to knee flexion mechanics during sport-specific tasks in this population.

Therefore, the current observational study intends to fill this research gap by exploring the impact of high vs. low FMS scores on knee flexion angle among recreational Kho-Kho players. Participants will be stratified based on established FMS thresholds (e.g., high ≥ 14 vs low < 14), and knee flexion angles will be quantitatively assessed during simulated locomotor and sport-related tasks using video or motion analysis methodologies. This investigation seeks to determine whether functional movement proficiency correlates with biomechanical movement quality providing insights to inform injury prevention, coaching, and functional training protocols tailored to Kho-Kho athletes.

2. FMS in Recreational Populations and Injury Prediction

Functional Movement Screening (FMS™) has been widely applied as a potential predictor for musculoskeletal injury in recreationally active individuals, though evidence across different athlete populations remains mixed.

In recreational sporting contexts, several studies have demonstrated meaningful associations between low FMS composite scores and heightened injury risk. For instance, a prospective study of 204 recreational athletes participating in dodge ball, 3-on-3 basketball, volleyball, and mini-football reported that individuals with FMS scores below 14 were 3.63 times more likely to sustain sport-related injuries (OR = 3.63) compared to higher-scoring peers, based on logistic regression analysis and ROC modeling [7]. Similarly, a prospective observational investigation over six months found that participants with FMS scores ≤ 14 had significantly higher incidence of

injury, with odds ratios approximating 6.97 (CI 2.98–16.35), underscoring the sensitivity of FMS in discerning movement quality in recreational adults [8].

In collegiate recreational populations, the predictive relationship between FMS and injury risk appears to be stronger when combined with additional risk factors. In one cohort of 160 collegiate athletes, those with FMS scores ≤ 14 in conjunction with a history of prior injury were at approximately 15-fold greater risk of sustaining new injuries compared to peers without such combination (positive likelihood ratio 5.8, increasing injury probability from 33% pretest to 74% posttest) [9]. This evidence suggests that FMS may be more effective when integrated within multifactorial injury risk models rather than used in isolation.

However, these promising findings are tempered by equivocal results in other athletic demographics. Among veteran football players aged over 32 years ($n = 238$), FMS composite scores did not significantly differ between injured and uninjured groups (mean scores: 11.7 ± 2.9 vs 12.2 ± 2.8 ; $p = 0.17$). Although players scoring >1 SD below the mean (≤ 10) had a higher injury incidence compared to those in the intermediate range (10–14), the difference was modest, and FMS demonstrated limited utility as a standalone predictor in this population [10].

Likewise, in NCAA Division II collegiate athletes (aged 18–24, $n = 257$), FMS performance yielded poor discriminative accuracy for injury prediction. The optimal cut score of ≤ 15 produced low sensitivity (~ 0.62 – 0.65), very low specificity (~ 0.49), and area under the curve (AUC) metrics between 0.53 and 0.56 across categories of musculoskeletal, overall, and severe injuries. Corresponding relative risks ranged narrowly between 1.24 and 1.45, indicating that FMS alone offered only a marginal improvement over chance in identifying those at risk [11].

Collectively, these findings reflect that while low FMS scores are often associated with increased injury risk in recreational and novice cohorts, FMS may be less predictive in older, veteran, or higher-level athletes. Contextual factors such as age, training background, previous injury history, and the specific athletic population appear to modulate the screening tool's predictive validity. Incorporating FMS within a multifactorial assessment framework, rather than relying on it as a solitary prognostic indicator, may enhance its clinical utility, especially among recreational sport settings.

3. Movement Screening and Biomechanics, with Emphasis on Knee Mechanics

Understanding the biomechanics of functional movement is critical when interpreting injury risk in athletic populations particularly in sports like Kho-Kho, where explosive, low-level, and high-velocity movements dominate. Building on the evidence surrounding injury prediction through the Functional Movement Screen (FMS), it is essential to explore the extent to which FMS relates to underlying biomechanical processes, particularly at the knee joint.

The FMS attempts to capture integrated elements of joint range of motion, muscle activation patterns, and inter-segmental coordination, particularly across weight-bearing joints such as the hips, knees, and ankles [12]. Each of its seven movement patterns challenges various aspects of neuromuscular control, mobility, and core stability. For example, performance in the deep squat a component often used to observe knee mechanics has been positively correlated with adequate dorsiflexion, knee flexion capacity, and hip mobility [13]. When performed correctly, the deep squat demonstrates that the ankles, knees, hips, thoracic spine, and shoulders are all moving in unison. When any of these regions are weak, the body might employ compensatory

patterns such as dynamic knee valgus or anterior knee displacement, which are associated with increased risk of injury.

Emerging studies exploring the relationship between FMS scores and joint kinematics have shown that people with higher FMS scores generally have more beneficial biomechanical profiles. MacLachlan et al. (2018) found that higher-scoring individuals in the FMS deep squat task had significantly better sagittal plane control and higher peak joint flexion angles for dynamic tasks, which reflects an aspect of biomechanical validity for the FMS scoring system [12]. These findings agree with earlier work by Butler et al., where it was shown that adjustments in squat mechanics such as reduced knee flexion or early heel rise might be linked with lower FMS scores [13]. Nevertheless, FMS has potential to quantify static and semi-dynamic control, but it still is unable to detect high-risk joint loading patterns in sports-specific movements. A major flaw in the FMS is that it isn't sensitive to specific tasks. For example, unplanned side-stepping or landing maneuvers, which are common in sports like Kho-Kho, need quick responses from the nervous system and changes in posture. A study involving female netball athletes indicated no significant correlation between FMS scores and peak knee valgus moments during sidestep cutting, a biomechanical parameter strongly associated with anterior cruciate ligament (ACL) injury risk [14]. When FMS is compared to other movement screening tools like the Landing Error Scoring System (LESS), this gap in predictive ability becomes even clearer. LESS is different from FMS in that it is meant to record fast, high-impact activities like jump landings and changes in direction. This gives a more direct view of biomechanical faults during sport-specific movements. LESS has shown stronger links to dynamic valgus collapse and strange knee kinematics, making it a better predictor of non-contact knee injuries in sports like basketball, football, and volleyball [15].

Additionally, studies on neuromuscular training have shown that enhancements in motion control, especially those affecting frontal plane knee stability, do not consistently manifest in post-intervention FMS scores. In a controlled trial with tactical athletes, substantial decreases in medial knee displacement during jump-landing tasks were noted after 12 weeks of neuromuscular training; however, the corresponding FMS scores showed no change [16]. This discovery prompts inquiries regarding the FMS's sensitivity to nuanced neuro-mechanical adaptations, particularly when such alterations transpire during swift, ballistic movements that are not mirrored within the controlled framework of FMS tasks. Given these constraints, it is clear that although FMS offers a fundamental assessment of movement proficiency, it may not comprehensively reflect the dynamic biomechanical challenges encountered by athletes in reactive, high-intensity sports such as Kho-Kho. Because of this, using it alone might miss important signs of injury risk, especially those related to unusual knee joint mechanics when under load. Using sport-specific tests like LESS or video-based kinematic analysis could give you a better picture, especially when looking at the knee flexion dynamics that are important for performance and injury in Kho-Kho players.

4. Knee Flexion Angle: Importance and Biomechanical Implications

The knee joint is a biomechanical fulcrum in many sports, and the angle of knee flexion is very important for changing how much weight is on the joint, how well it absorbs shock, and how well it moves. To safely spread forces across articular surfaces, tendons, ligaments, and the muscles around the knee, it is important to control knee flexion properly. In dynamic sports like Kho-Kho, where sprinting, sudden stops, and quick changes of direction happen all the time, having the best knee flexion mechanics is very important for both performance and avoiding injuries.

Biomechanically, the knee flexion angle will have a direct impact on how much load is transferred to the tibiofemoral and patellofemoral joints and where it is distributed. During weight-bearing activities, greater knee flexion angles assist the quadriceps and hamstrings to contract eccentrically, which assists with more shock absorption and reduces the peak ground reaction forces that are transmitted to the joint structures [17]. On the other hand, reduced knee flexion angles, which are typically a sign of a stiffer pattern of movement or landing, have been associated with greater joint loading rates and changed force vectors. This can make them more prone to developing overuse injuries and ligamentous stress [18]. Another important feature of knee flexion mechanics is its connection with the patellofemoral joint.

Patellofemoral pain syndrome (PFPS), an overuse injury among sports players, is commonly associated with disrupted patellar tracking and increased joint stress secondary to abnormal knee flexion angles during dynamic activities such as squatting, running, and jumping [19]. With decreased knee flexion upon landing or squatting, patellofemoral joint reaction forces become greater as the knee is unable to handle the load as effectively by flexion excursion [20]. Poor knee flexion not only amplifies compressive forces but can also worsen lateral patellar displacement, leading to pain and functional restriction. Rehabilitation methods that enhance knee flexion mechanics have been found to effectively terminate PFPS symptoms, underlining the clinical significance of this biomechanical factor [21]. Beyond patellofemoral disease, knee flexion angle is also significant in the mechanisms of anterior cruciate ligament (ACL) injury. The ACL is susceptible to injury under excessive anterior tibial translation with valgus collapse, especially in relatively extended knee positions (i.e., low knee flexion angles). [22].

During cutting and landing actions, athletes who have shallow knee flexion angles often less than 30 degrees exhibit significantly greater ACL strain and injury risk compared to those athletes who possess greater knee flexion [23].

This compromised flexion limits knee capacity for impact force dissipation, and the load is transmitted to passive ligamentous structures.. In addition, neuromuscular impairments that restrict knee flexion can lead to compensatory movement patterns like dynamic valgus and trunk displacement, further increasing ACL injury risk [24]. This biomechanical knowledge reflects why knee flexion angle is often used as a primary metric for both injury prevention screening and rehabilitation monitoring. For instance, training regimens that focus on plyometric training with instruction to enhance knee flexion angles during landing have been demonstrated to decrease injury occurrence among athletes by facilitating safer joint mechanics [25]. Additionally, motion analysis studies often use peak knee flexion angle during sport-specific tasks as a biomechanical indicator of movement quality and injury susceptibility [26].

Despite its importance, altered knee flexion mechanics remain a common finding in both recreational and elite athletes, especially in those with a history of knee pain or injury. Movement deficiencies identified through screening tools like the Functional Movement Screen (FMS) may indirectly reflect altered knee flexion control, but as discussed earlier, FMS's sensitivity to detect dynamic joint angles remains limited. Consequently, objective measurement of knee flexion angle through motion capture or video analysis is essential to provide detailed insight into an athlete's biomechanical profile.

In summary, the knee flexion angle is a cornerstone of healthy movement patterns and joint function. Its modulation directly influences load distribution, injury risk, and the

quality of athletic performance. Alterations in knee flexion mechanics are strongly associated with increased risk for common knee disorders such as PFPS and ACL injury, emphasizing the necessity for focused assessment and training to optimize knee flexion during dynamic activities.

5. Kho-Kho: Sport-Specific Movement Demands and Relevance

Kho-Kho is a traditional Indian tag sport that is very fast-paced and requires a lot of agility, balance, and coordination in the lower body. To avoid opponents or get tags, players quickly speed up and slow down, change direction often, and stay crouched for long periods of time. These movement patterns create unique biomechanical problems, especially for the knee joint. To get the best performance and avoid injury, you need to know a lot about how joints work. The basic idea behind Kho-Kho is to run quickly, stop suddenly, and turn quickly in a small area [27]. The crouching position, which is often used when playing defense or "chasing" opponents, puts a lot of stress on the knee extensors and flexors. This is because the patellofemoral joint is under more pressure when you are in this position [28]. To keep the joint stable, you need both muscular endurance and neuromuscular control when you crouch and move quickly. Additionally, the repeated high-speed decelerations that are typical of Kho-Kho increase the anterior shear forces at the knee, which could put stress on the anterior cruciate ligament (ACL) and other structures that help keep the knee stable [29]. Because these movements happen quickly and in an unpredictable way, players need to have very good neuromuscular coordination to change the angle of their knee flexion and keep their biomechanics in good shape while they play. Poor movement control or changes in knee flexion strategies while cutting or landing may raise the risk of injury, as seen in other field sports with similar movement requirements, like

football and rugby [30]. For instance, inadequate knee flexion during sudden deceleration can intensify impact forces, leading to joint overloading and heightened vulnerability to ligamentous injuries or patellofemoral pain [31]. Even though Kho-Kho is becoming more popular, there is still a lack of research on sport-specific biomechanics and movement screening for this sport. Numerous studies have examined injury epidemiology and overall physical conditioning among Kho-Kho players; however, comprehensive analyses of movement mechanics, particularly concerning knee flexion during sport-specific tasks, remain scarce [32] This lack in the literature highlights the pressing need to identify the unique biomechanical needs of Kho-Kho through the use of tools like the Functional Movement Screen (FMS) in combination with biomechanical assessments, such as 3D motion capture or force plate testing.

In order to design injury prevention and performance enhancement plans that are effective for every sport, one must understand these movement patterns. Knowing, for instance, the typical knee flexion angles of typical Kho-Kho movements can assist in specific neuromuscular training that stabilizes you and makes you less susceptible to injury. In addition, understanding biomechanical deficits or compensatory movement patterns in recreational athletes, who often do not have professional training, is vital to creating reliable screening protocols and conditioning programs. [33].

This observational research intends to bridge the gap in research by investigating the influence of high and low FMS scores on knee flexion angle in recreational Kho-Kho players. This research aims to advance knowledge regarding movement-injury connection within the lesser-studied population of Kho-Kho players by associating functional movement quality with biomechanical measures specific to the demands

of the sport.

Owing to the complex and challenging mechanics of the knee in Kho-Kho, an understanding of the interaction between functional movement quality and biomechanical risk factors is of critical importance in preventing injury in amateur players. The Functional Movement Screen (FMS) provides an easy method of screening movement competence; however, its specific correlation with knee flexion angles and the related injury risk within this population has not been exhaustively explored. The dynamic actions in Kho-Kho, including high accelerations and decelerations, direction changes, and crouching, pose special biomechanical demands that need careful attention. The current gap in studies calls for an examination of how FMS categories (high vs. low scores) relate to key biomechanical variables like knee flexion angle, and how the overall influence of such variables contributes to the prevalence of injuries. Demonstrating this link will clarify if functional movement screening can be used to accurately predict knee joint loading patterns that are responsible for non-contact musculoskeletal injuries among Kho-Kho players. This background establishes the groundwork for the current study, which aims to systematically assess these relationships. The subsequent section delineates the study's aim and objectives, directing the examination of the biomechanical and functional predictors of injury risk among recreational Kho-Kho athletes.

NEED FOR THE STUDY

On synthesizing the available literature, despite extensive analysis in elite athletes, there is limited understanding of how knee flexion angle functions as a risk marker in recreational Kho-Kho Players. Studies have combined FMS-based risk stratification with quantitative knee flexion angle analysis using video tools like 3D motion analysis, leaving a methodological gap that a 2D motion analysis can be used to identify the knee flexion angle in kho-kho players. Addressing this gap can enable early identification of at-risk individuals and the design of targeted training interventions to correct harmful movement patterns and reduce knee injury incidence.

AIM AND OBJECTIVE OF THE STUDY

AIM OF THE STUDY

To evaluate the impact of knee joint flexion angle on injury prevalence among recreational Kho-Kho players, using FMS as a screening tool

OBJECTIVES OF THE STUDY

To determine the correlation between knee flexion angles and FMS score in recreational Kho-Kho players.

HYPOTHESIS OF THE STUDY

Null Hypothesis: There is no significant difference in peak knee flexion angle between recreational Kho-Kho players classified as high risk and those classified as low-risk based on the Functional Movement Screen

Alternate Hypothesis: Recreational Kho-Kho players with high-risk FMS scores will exhibit significantly lower peak knee flexion angles compared to those with low-risk scores, reflecting stiffer landing mechanics associated with increased knee injury risk

REVIEW OF LITERATURE

1. Cook G, Burton L, Hoogenboom BJ, Voight M. “Functional movement screening: the use of fundamental movements as an assessment of function - part 1.” (2014)

[International Journal of Sports Physical Therapy]

This study explored the concept and application of the Functional Movement Screen (FMS) as a tool to assess fundamental movement patterns in athletes and active individuals. The authors emphasized the importance of identifying movement asymmetries and limitations that may predispose individuals to injury or hinder performance. The FMS is presented as a screening tool rather than a diagnostic method, aiming to guide corrective exercises and training modifications. The study highlights how structured movement assessments can play a critical role in injury prevention strategies and performance optimization, particularly in athletic and rehabilitation settings.

2. Kiesel K, Plisky PJ, Voight ML. “Can serious injury in professional football be predicted by a preseason Functional Movement Screen?” (2007)

[North American Journal of Sports Physical Therapy]

This study investigated whether the Functional Movement Screen (FMS) could be used as a predictive tool for serious injuries in professional football players during the competitive season. The researchers evaluated players using the FMS during preseason and tracked injury data throughout the season. Findings indicated that players who scored 14 or below on the FMS were significantly more likely to sustain serious injuries. The study supports

the use of FMS as a preseason screening tool to identify athletes at increased risk, suggesting its value in designing preventive training interventions to reduce injury incidence in high-performance sports environments.

3. Pamukoff DN, Holmes SC, Heredia CE, Gonzales CE, Shumski EJ, Montgomery MM. “Association between the Functional Movement Screen and landing kinematics in individuals with and without anterior cruciate ligament reconstruction.” (2022)

[Journal of Sport Rehabilitation]

This study examined the relationship between Functional Movement Screen (FMS) scores and landing kinematics in individuals with a history of anterior cruciate ligament (ACL) reconstruction compared to healthy controls. The researchers aimed to determine whether FMS could reflect underlying biomechanical differences during landing tasks, which are often linked to re-injury risk. Results showed limited associations between total FMS scores and specific landing mechanics, suggesting that while FMS can highlight general movement quality, it may not fully capture complex biomechanical deficits relevant to ACL injury rehabilitation. The findings emphasize the need for complementary assessments in return-to-sport decisions post-ACL reconstruction.

4. Butler RJ, Plisky PJ, Southers C, Scoma C, Kiesel KB. “Biomechanical analysis of the different classifications of the Functional Movement Screen deep squat test.” (2010)

[Sports Biomechanics]

This study conducted a biomechanical evaluation of the deep squat component of the Functional Movement Screen (FMS), focusing on how different performance classifications reflect underlying movement mechanics. Using motion analysis, the researchers compared joint angles and kinematic patterns among subjects assigned to varying FMS deep squat scores. Results revealed that lower FMS scores were associated with limited joint mobility and altered movement patterns, particularly in the hips, knees, and ankles. The study supports the validity of the FMS deep squat as a screening tool for detecting functional limitations and highlights the biomechanical distinctions that underlie different score classifications.

5. Hewett TE, Myer GD, Ford KR. “Anterior cruciate ligament injuries in female athletes: Part 1, mechanisms and risk factors.” (2006)
[The American Journal of Sports Medicine]

This foundational study investigated the biomechanical and neuromuscular mechanisms contributing to the high incidence of anterior cruciate ligament (ACL) injuries in female athletes. The authors identified key risk factors, including valgus knee positioning, poor neuromuscular control, and hormonal influences, which contribute to increased ACL injury susceptibility during high-impact activities like jumping and cutting. The study emphasized the need for targeted injury prevention programs that address modifiable risk factors through neuromuscular and biomechanical training. Its findings laid critical groundwork for future research and intervention strategies aimed at reducing ACL injury rates, particularly among female populations in competitive sports.

6. Paterno MV, Myer GD, Ford KR, Hewett TE. “Neuromuscular training improves single-limb stability in young female athletes.” (2004)

[Journal of Orthopaedic & Sports Physical Therapy]

This study examined the effects of a neuromuscular training program on single-limb stability in young female athletes, a population at elevated risk for lower extremity injuries such as ACL tears. The intervention focused on enhancing balance, proprioception, and muscular control through targeted exercises. Post-training assessments showed significant improvements in single-leg postural stability, suggesting that neuromuscular training can effectively address deficits that contribute to injury risk. The findings support incorporating such programs into youth athletic training, particularly for females, to enhance functional stability and reduce the likelihood of non-contact lower limb injuries.

7. Gabbett TJ. “Influence of training and match intensity on injuries in rugby league.” (2004)

[Journal of Sports Sciences]

This study explored the relationship between training and match intensity and the incidence of injuries in semi-professional rugby league players. By monitoring physical workloads and injury rates over a competitive season, the research found that higher training and match intensities were associated with increased injury risk, particularly when spikes in workload were not adequately managed. The study emphasized the importance of load management and progressive conditioning to prevent overload injuries. These findings contribute to the development of evidence-based training

strategies aimed at optimizing performance while minimizing injury risk in contact sports like rugby league.

8. Orchard J, Seward H. "Epidemiology of injuries in the Australian Football League, seasons 1997–2000." (2002)

[British Journal of Sports Medicine]

This study provided a comprehensive epidemiological analysis of injury patterns in the Australian Football League (AFL) over four seasons. By systematically recording injury incidence, types, and time lost, the research identified common injuries such as hamstring strains, knee ligament injuries, and groin strains. The data highlighted the high physical demands of AFL and the importance of targeted injury prevention strategies. The study also established a valuable injury surveillance model for professional team sports, contributing significantly to the understanding of injury trends and informing the development of medical and training protocols within elite-level football.

9. Parchmann CJ, McBride JM. "Relationship between Functional Movement Screen and athletic performance." (2011)

[Journal of Strength and Conditioning Research]

This study investigated the association between Functional Movement Screen (FMS) scores and various measures of athletic performance, including power, speed, and agility in collegiate athletes. The authors aimed to determine whether FMS could serve as an indicator of performance capacity beyond injury risk screening. Results revealed weak to moderate

correlations between FMS scores and certain performance metrics, suggesting that while FMS is useful for assessing movement quality and potential injury risk, it may have limited predictive value for specific athletic performance outcomes. The study highlights the need for complementary assessments when evaluating athlete readiness and performance potential.

10. Martin C, Olivier B, Benjamin N. “The Functional Movement Screen in the prediction of injury in adolescent cricket pace bowlers: An observational study.” (2017)

[Journal of Sport Rehabilitation]

This observational study examined the effectiveness of the Functional Movement Screen (FMS) in predicting injury risk among adolescent cricket pace bowlers. The researchers assessed preseason FMS scores and tracked injury occurrences throughout the playing season. Findings indicated that lower FMS scores were associated with a higher incidence of musculoskeletal injuries, supporting the use of FMS as a practical screening tool in this athletic population. The study highlights the value of movement screening in early identification of at-risk athletes and emphasizes the potential for targeted intervention programs to reduce injury rates in youth cricket.

11. Dorrel BS, Long T, Shaffer S, Myer GD. “Evaluation of the Functional Movement Screen as an injury prediction tool among active adult populations: A systematic review and meta-analysis.” (2015)

[Sports Health]

This systematic review and meta-analysis evaluated the effectiveness of the Functional Movement Screen (FMS) as a predictive tool for injury risk across various active adult populations. By synthesizing data from multiple studies, the authors assessed the sensitivity and specificity of FMS scores in identifying individuals at increased injury risk. The analysis revealed that while low FMS scores are somewhat associated with higher injury risk, the predictive accuracy varies widely depending on the population and injury type. The study concludes that FMS should be used as part of a broader assessment strategy rather than as a standalone predictor, highlighting the need for integrated approaches in injury prevention programs.

12. Balsalobre-Fernández C, Tejero-González CM, del Campo-Vecino J, Bavaresco N. “The concurrent validity and reliability of a low-cost, high-speed camera-based method for measuring the flight time of vertical jumps.” (2014)

[Journal of Strength and Conditioning Research]

This study assessed the validity and reliability of a low-cost, high-speed camera system as a method for measuring flight time during vertical jump tests. The authors compared the camera-based measurements against a force platform, considered the gold standard, to determine accuracy. Results demonstrated strong concurrent validity and high test-retest reliability, supporting the use of this affordable technology in practical and field settings. The findings suggest that high-speed camera systems can serve as effective, accessible tools for evaluating jump performance, particularly in environments lacking expensive laboratory equipment.

13. Damsted C, Nielsen RO, Larsen LH. “Reliability of video-based quantification of the knee- and hip angle at foot strike during running.” (2015)

[International Journal of Sports Physical Therapy]

This study investigated the reliability of using video-based analysis to measure knee and hip angles at foot strike during running. By comparing repeated measurements across different raters and sessions, the authors aimed to determine the consistency of video-based joint angle assessments in a clinical and field setting. The findings demonstrated moderate to high reliability, supporting the use of video analysis as a practical tool for assessing lower limb biomechanics during running. This method offers a cost-effective and accessible alternative to more complex motion capture systems, beneficial for injury risk assessment and gait analysis.

14. Irving F, Russell J, Smith T. “Reliability of knee joint position sense measurement: a comparison between goniometry and image capture methods.” (2016)

[European Journal of Physiotherapy]

This study compared the reliability of two methods for measuring knee joint position sense: traditional goniometry and image capture analysis. The researchers evaluated intra- and inter-rater reliability for both techniques in healthy subjects. Results showed that both methods demonstrated acceptable reliability, with image capture providing slightly higher consistency and potential for more precise measurement. The study

highlights the advantages of image capture technology in improving objectivity and repeatability in proprioceptive assessments, suggesting its usefulness in both clinical and research settings focused on knee joint function.

15. Bonazza NA, Smuin D, Onks CA, Silvis ML, Dhawan A. “Reliability, validity, and injury predictive value of the Functional Movement Screen: A systematic review and meta-analysis.” (2017)

[The American Journal of Sports Medicine]

This systematic review and meta-analysis evaluated the reliability, validity, and injury predictive capability of the Functional Movement Screen (FMS) across multiple populations and sports. The study synthesized data from various research articles to assess consistency of FMS scoring, its accuracy in detecting movement dysfunction, and its effectiveness in predicting injury risk. Findings indicated that while FMS is reliable and valid for assessing movement patterns, its ability to predict injury remains moderate and context-dependent. The authors recommend using FMS as part of a comprehensive assessment strategy rather than a standalone tool for injury prevention.

16. Shultz R, Anderson SC, Matheson GO, Marcello B, Besier T. “Test-retest and interrater reliability of the Functional Movement Screen.” (2013)

[Journal of Athletic Training]

This study assessed the test-retest and interrater reliability of the Functional Movement Screen (FMS) across a diverse athletic population. By evaluating

consistency of scoring both within the same rater over time and between different raters, the research aimed to confirm the reproducibility of FMS assessments. Results demonstrated good to excellent reliability, supporting FMS as a consistent tool for evaluating movement patterns in both clinical and sports settings. The findings reinforce the FMS's applicability in injury risk screening and movement quality assessments, provided that raters are adequately trained.

17. Teyhen DS, Shaffer SW, Lorenson CL, Halfpap JP, Donofry DF, Walker MJ, Dugan JL, Childs JD. "The Functional Movement Screen: a reliability study." (2012)

[Journal of Orthopaedic & Sports Physical Therapy]

This study examined the reliability of the Functional Movement Screen (FMS) across multiple raters with varying levels of experience. The researchers evaluated test-retest and interrater reliability to determine the consistency of FMS scoring in clinical settings. Findings indicated high reliability when raters received standardized training, highlighting the importance of proper instruction in administering the FMS. The study supports the use of FMS as a reliable assessment tool for identifying movement dysfunction and potential injury risk in diverse populations.

18. Frost DM, Beach TA, Callaghan JP, McGill SM. "Using the Functional Movement Screen™ to evaluate the effectiveness of training." (2012)

[Journal of Strength and Conditioning Research]

This study investigated the utility of the Functional Movement Screen (FMS) in assessing changes in movement quality following a structured training program. The researchers measured FMS scores before and after an intervention designed to improve mobility and stability in active adults. Results demonstrated significant improvements in FMS scores post-training, suggesting that FMS is a sensitive tool for detecting functional adaptations to exercise. The findings support the application of FMS in monitoring training effectiveness and guiding individualized corrective strategies to enhance movement competency and reduce injury risk.

19. Butler RJ, Contreras M, Burton LC, Plisky PJ, Goode A, Kiesel K. “Modifiable risk factors predict injuries in firefighters during training academies.” (2013)

[Work]

This study examined the role of modifiable risk factors, including Functional Movement Screen (FMS) scores, in predicting injuries among firefighters during their training academies. The researchers assessed movement quality and physical fitness variables before training and tracked injury incidence throughout the academy period. Findings revealed that poor movement patterns and lower FMS scores were significantly associated with higher injury risk. The study emphasizes the importance of early identification and correction of modifiable risk factors to reduce injury rates in physically demanding occupations such as firefighting.

20. Warren M, Lininger MR, Chimera NJ, Smith CA. “Utility of FMS to understand injury incidence in sports: current perspectives.” (2018)

[Open Access Journal of Sports Medicine]

This review article examined the current evidence regarding the Functional Movement Screen (FMS) and its utility in understanding and predicting injury incidence in various sports. The authors critically evaluated the strengths and limitations of FMS as a screening tool, highlighting its role in identifying movement dysfunctions that may contribute to injury risk. The review acknowledged mixed findings across studies but emphasized the potential of FMS when combined with other assessments and tailored interventions. It advocates for continued research and integration of FMS within comprehensive injury prevention frameworks in athletic populations.

21. Padua DA, Bell DR, Clark MA. “Neuromuscular characteristics of individuals displaying excessive medial knee displacement.” (2012)

[Journal of Athletic Training]

This study investigated the neuromuscular factors associated with excessive medial knee displacement (MKD), a movement pattern linked to increased injury risk, particularly in the knee joint. The researchers analyzed muscle activation patterns, strength, and control in individuals exhibiting MKD during functional tasks. Results indicated that deficits in hip abductor and external rotator muscle function contribute to MKD, highlighting the importance of targeted neuromuscular training for injury prevention. The findings provide valuable insight into biomechanical contributors to knee injuries and inform the development of rehabilitation and conditioning programs aimed at correcting maladaptive movement patterns.

MATERIALS AND METHODOLOGY

- **STUDY POPULATION :** Recreational kho-kho players
- **STUDY DESIGN:** Observational study
- **SAMPLING TECHNIQUE:** Purposive sampling
- **SAMPLE CRITERIA:**

INCLUSION CRITERIA: Recreational kho-kho players

- 13-25 years old
- Players who are actively participating in any event, school/college/university level tournaments with a minimum experience.
- Both male and female participants
- Players who have the ability to perform and complete the task.
- Players who are willing to commit to the duration of the study.

EXCLUSION CRITERIA:

- Any current pathology or trauma
 - Any lower extremity surgery in the past 6 months
 - Any pre-existing condition such as recent physical injuries, musculoskeletal disorder
- **STUDY SETTING:** Kho-Kho HPC, AM/NS, Puri, Odisha
 - **SAMPLE SIZE:** 95
 - **STUDY DURATION:** 1 year
 - **Ethical clearance:** 6 months
 - **Sample selection, data collection:** 4 months
 - **Statistical analysis, results analysis, discussion:** 2 months

➤ **MATERIALS REQUIRED:**

- Camera

- Tripod
- FMS Kit
- Dowel rod
- Measuring tape

➤ **OUTCOME MEASURES**

FMS- Functional Movement Screening

The Functional Movement Screen (FMS) is a widely used assessment tool designed to evaluate the quality of fundamental movement patterns in individuals who are not currently injured. It consists of seven key tests- deep squat, hurdle step, inline lunge, shoulder mobility, active straight-leg raise, trunk stability push-up, and rotary stability which collectively assess mobility, stability, balance, and overall movement control. Each test is scored on a scale from 0 to 3, with a maximum total score of 21. A score of 14 or below is commonly associated with a higher risk of injury, particularly in athletic populations, whereas scores above 14 typically indicate a lower injury risk and more efficient movement patterns. The FMS is not a diagnostic tool for medical conditions but serves as an effective screening method to identify movement limitations or asymmetries. These insights enable coaches, trainers, and clinicians to design targeted corrective strategies aimed at reducing injury risk and enhancing performance.

Joint angle analysis- Kinovea 2D analysis

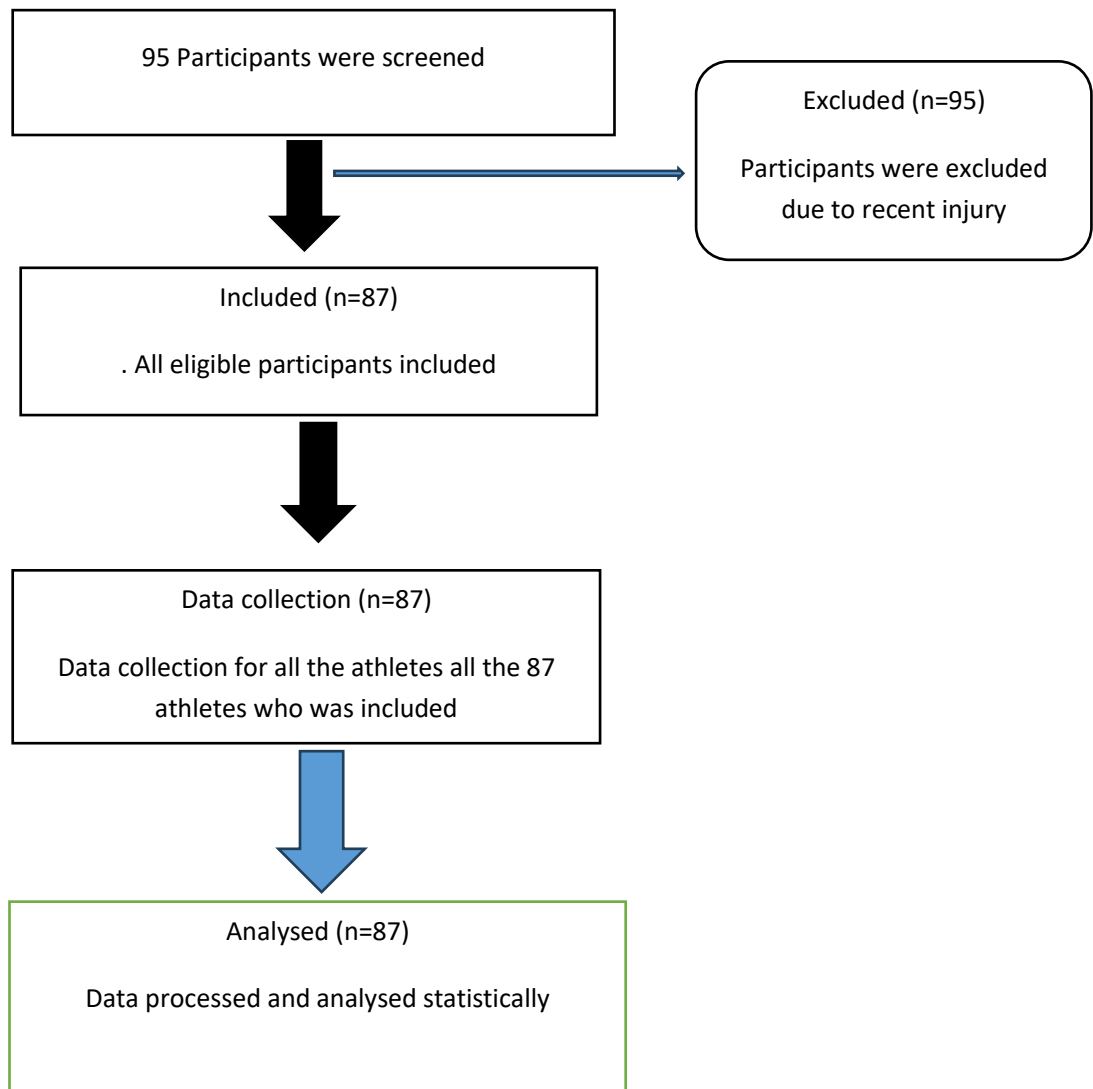
2D movement analysis is a way to look at how people move by recording and studying their motion in two dimensions. This is usually done with video recordings from one

plane, either the sagittal (side view) or frontal (front/back view). This kind of analysis is very common in clinics, sports, and rehabilitation settings because it is cheaper, easier to get to, and easier to use than more advanced 3D systems.

Standard video cameras (often with simple software) are used to record movements like squats, lunges, walking, or jumping in a 2D setup. To help with measuring joint angles, postural alignment, or deviations from ideal movement patterns, markers can be put on anatomical landmarks like joints. After that, the software analyzes the footage by breaking it down frame by frame, measuring angles, and comparing it side by side. Even though 2D analysis isn't perfect like when it can't accurately capture complex or out-of-plane movements it is still a useful tool for initial screening, movement pattern analysis, and tracking progress over time. It works even better when used with functional tests like the Functional Movement Screen (FMS) , which gives you a more visual and measurable way to look at movement quality and find compensations or asymmetries that could raise the risk of injury.

Single leg squat

FLOW CHART



PROCEDURE

Approval from the IEC of ABHINAV BINDRA SPORTS MEDICINE AND RESEARCH INSTITUTE (Annexure – c.1) was obtained. For data retrieval, players were assessed and recorded to the Sports analysis in Excel Sheet

PHASE I

In between July 2025 to August 2025 data was collected. A total of 87 players were assessed and participants video was taken in order to analyse.

PHASE II

A total 95 participants' movement analysis was done during this phase. FMS was done on the 87 participants and then were divided into high and low risk according to the FMS score.

PHASE III

Six markers were placed on each right and left Greater trochanter (for hip reference), lateral femoral epicondyle (for knee joint reference) and lateral malleolus of the fibula (ankle reference). Individual is then asked to perform single leg squat on both the legs. Video was then recorded from the beginning and the end point

PHASE IV

PREPARATION OF THE PARTICIPANTS

Both the male and female were instructed to wear tight fit pants/shorts and t-shirts.

PHASE V

Bony landmarks: Greater Trochanter, Lateral Femoral Epicondyle and Lateral Malleolus

Surface: Indoor kho-kho court and even surface.

Distance of camera: 3 meters (Lateral view)

Height of camera: Sagittal plane camera view camera placement and anatomical landmarks placement for single leg squat.

All the participants were thoroughly explained the procedure, informed consent was obtained from all the participants. Participants age, gender, height were collected. Following this the participants were asked to change into suitable clothing and skin markers were applied over Greater trochanter, lateral femoral epicondyle and lateral malleolus. Participants were instructed to perform single leg squat on a cue of start, which was recorded using the camera.



FIGURE 1- FEMALE PLAYER DOING SINGLE LEG SQUAT FOR KINOVEA

FIGURE 2- MALE PLAYER SINGLE LEG SQUAT FOR KINOVEA

There were no adverse event while performing test.

PHASE VI

Data was captured using a camera, Data processing was done in 2D software Kinovea. Descriptive analysis was done for demographic characteristics of participants. Angle (maximum ROM) in degrees in single leg squat test, 2d motion analysis system for kinematic analysis. The values recorded for knee flexion angle for the category 13-21 years of age group on right leg and left leg respectively. Statistical analysis of the data was performed for all 87 participants using SPSS version 27.

STATISTICAL ANALYSIS

Data were analyzed using SPSS version 27. Normality of continuous variables was assessed using the Kolmogorov–Smirnov test ($n = 87$). Variables not normally distributed were analyzed with nonparametric tests. Since the FMS score and age were non-normal, Spearman’s correlation was used instead of Pearson to determine associations between FMS score and continuous predictors (age, height, weight, knee flexions). Independent t-tests or Mann–Whitney U tests compared continuous variables across gender and risk groups. Chi-square tests assessed associations between categorical variables, with significance set at $p < 0.05$.

RESULTS

Descriptive Statistics with Normality Test (Shapiro-Wilk)

Sl. No	Variables	Mean \pm SD	p-value
1	Age	17.64 \pm 2.16	< .001
2	Height	166.57 \pm 9.68	.223
3	Weight	60.00 \pm 9.23	.282
4	Gender	1.30 \pm 0.46	-
5	FMS Score	14.05 \pm 3.99	< .001
6	Right Knee Flexion Angle	75.82 \pm 7.25	.818
7	Left Knee Flexion Angle	79.86 \pm 4.04	.424

Table 1. Tests of Normality for Continuous Variables

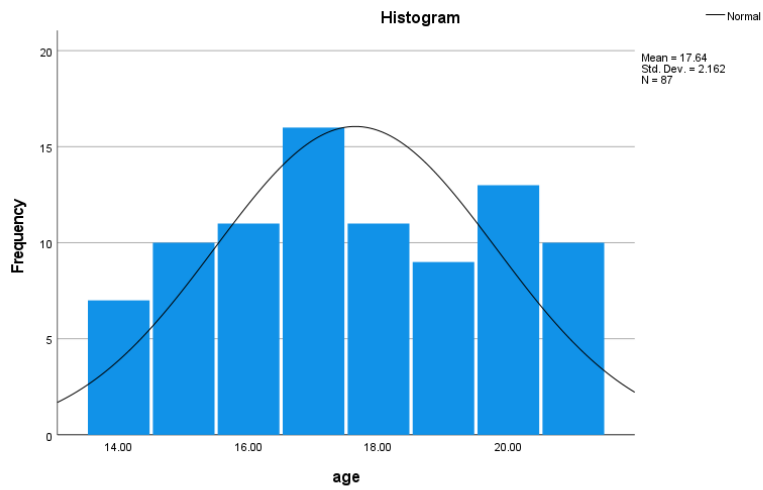
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
AGE	.126	87	.002	.937	87	.000
HEIGHT	.074	87	.200*	.981	87	.223
WEIGHT	.072	87	.200*	.982	87	.282
FMSSCORE	.150	87	.000	.919	87	.000
RIGHTKNEEFLEXION	.040	87	.200*	.991	87	.818
LEFT KNEE FLEXION	.051	87	.200*	.985	87	.424

*. This is a lower bound of the true significance.

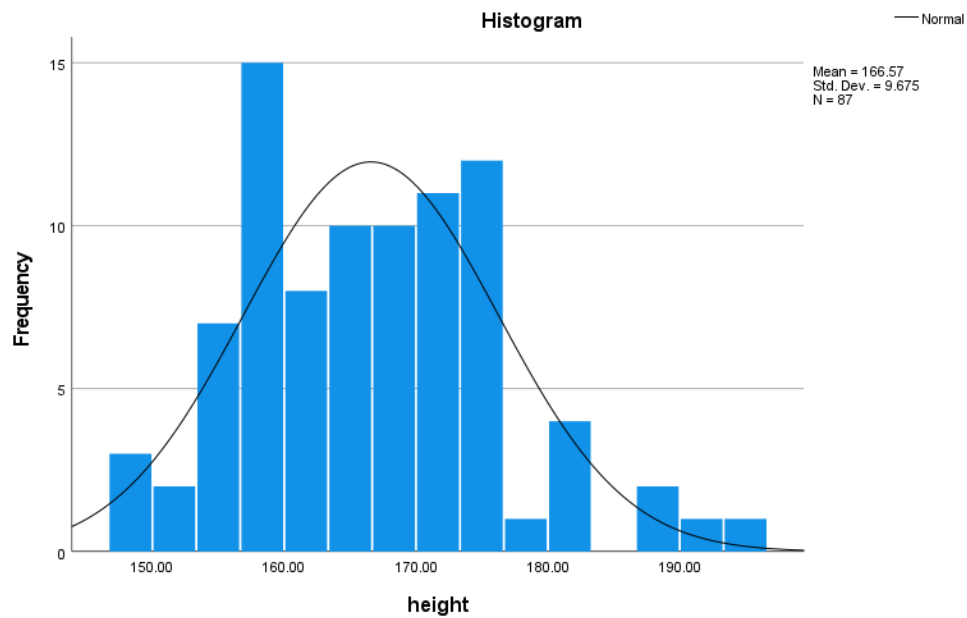
a. Lilliefors Significance Correction

Table 1 shows the results of normality tests (Kolmogorov-Smirnov and Shapiro-Wilk) conducted for six continuous variables to assess their distributional properties. Based on the Shapiro-Wilk test, which is considered more appropriate for the given sample size ($n = 87$), four variables height ($p = 0.223$), weight ($p = 0.282$), right knee flexion ($p = 0.818$), and left knee flexion ($p = 0.424$) exhibited no significant deviation from normality ($p > 0.05$), suggesting that they are approximately normally distributed. In contrast, age ($p = 0.000$) and FMS score ($p = 0.000$) yielded significant results, indicating a departure from the normal distribution. These outcomes have implications for the choice of statistical analyses, where parametric methods may be

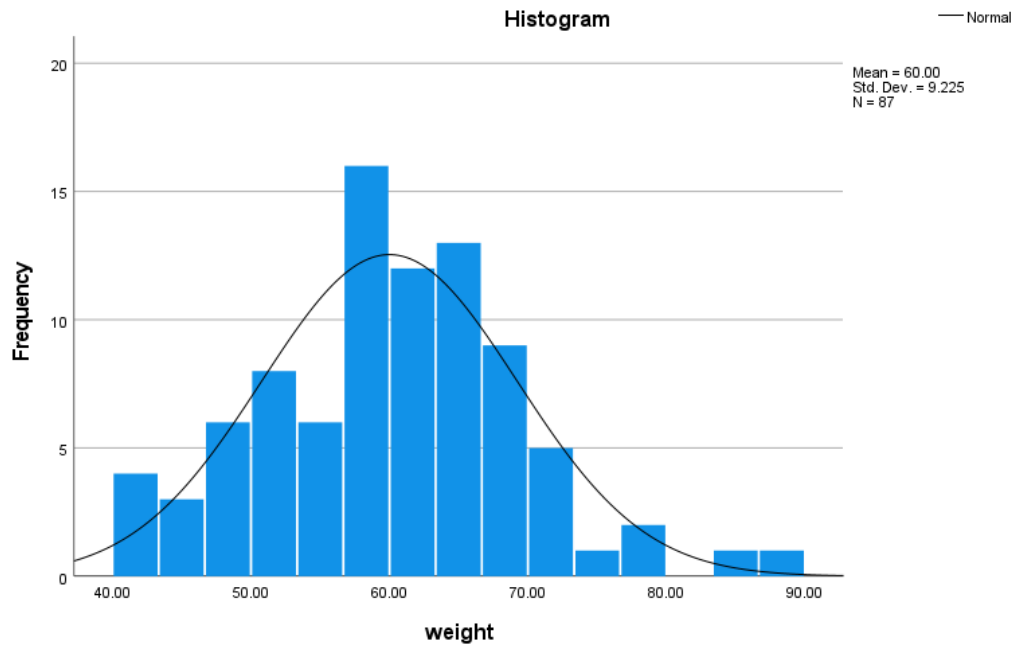
appropriately applied to normally distributed variables, while non-parametric alternatives should be considered for those that violate the normality assumption.



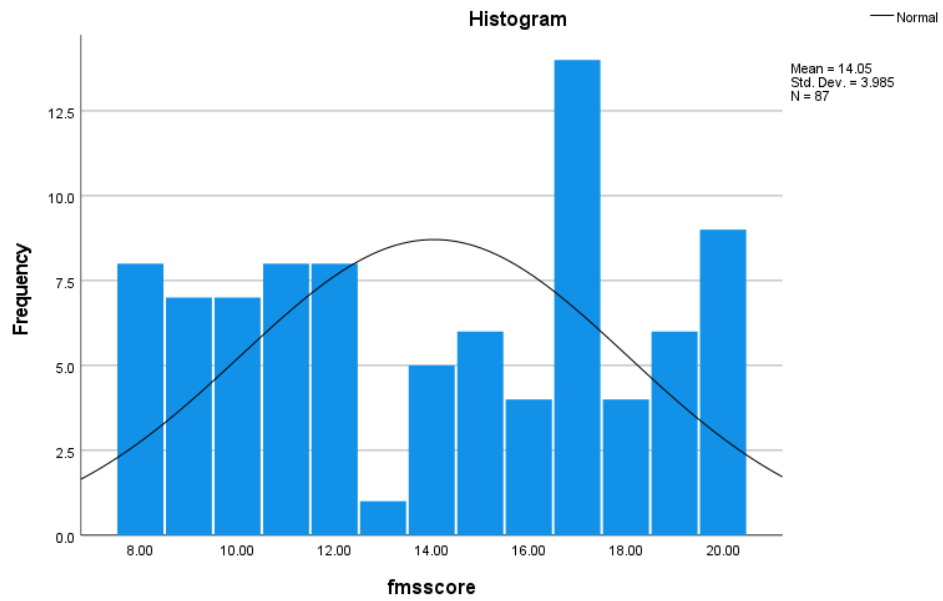
GRAPH 1 Normality plot of AGE



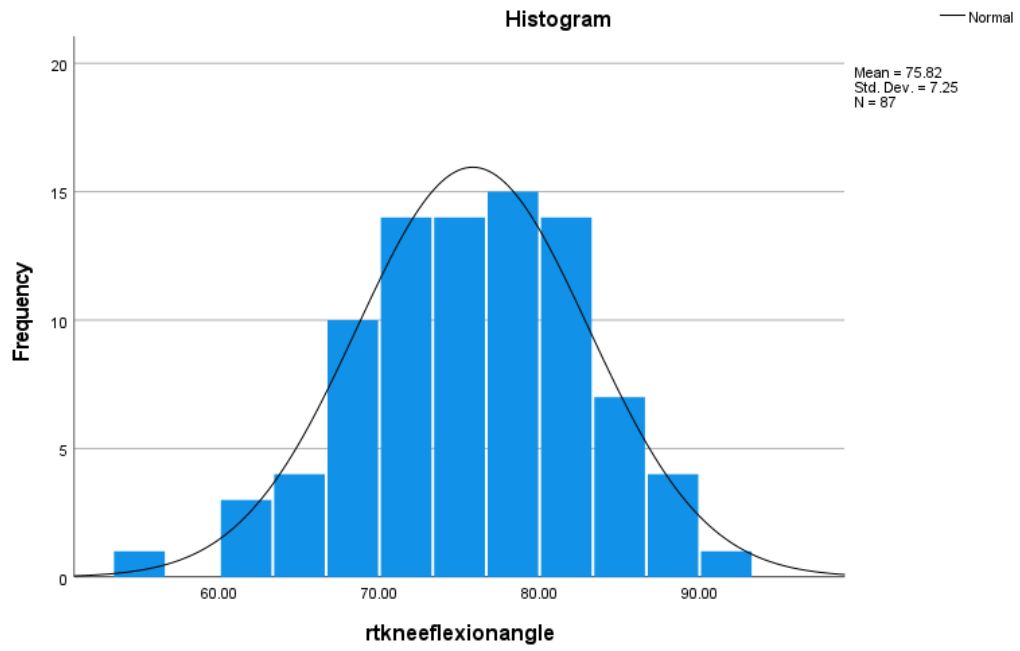
GRAPH 2 Normality plot of height



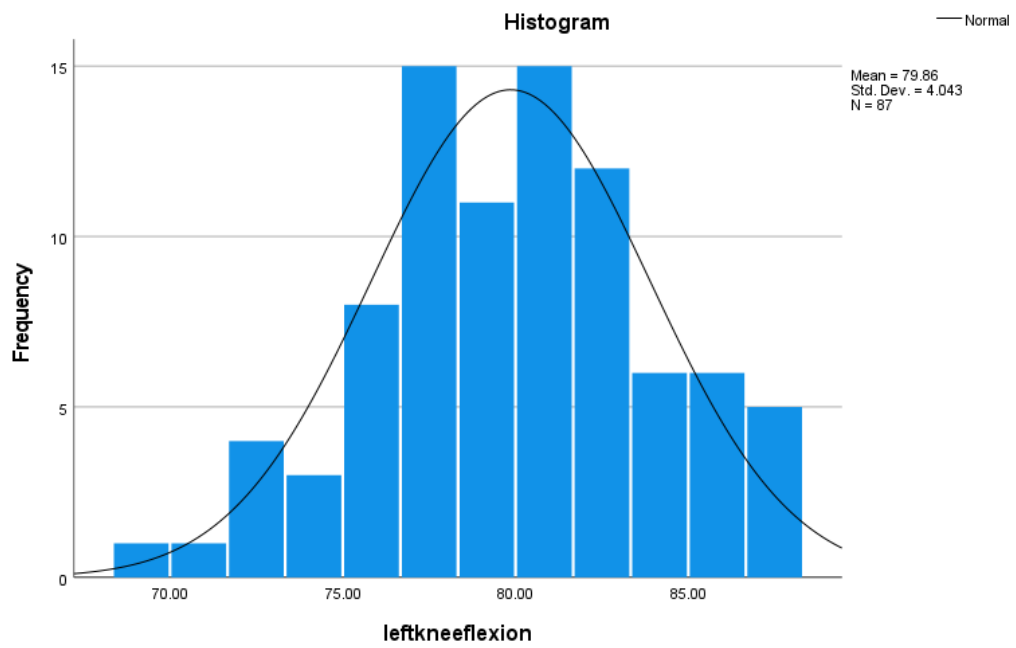
GRAPH 3 Normality plot of weight



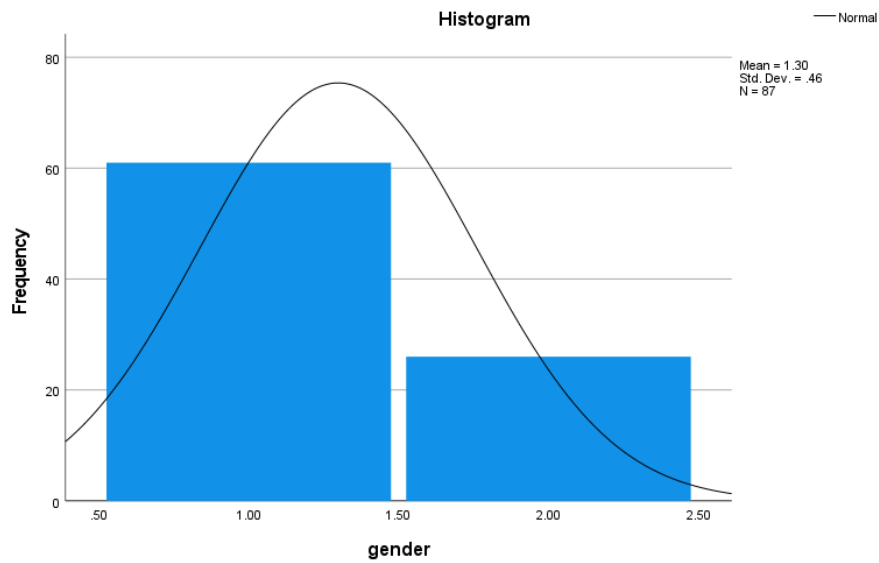
GRAPH 4 Normality plot of FMS



GRAPH 5 Normality plot of Right knee flexion angle



GRAPH 6 Normality plot of Left knee flexion angle



GRAPH 7 Normality plot of gender

			AGE	HEIG HT	WEIG HT	FMSSCORE	RIGHTKNEEF LEXION	LEFTKNEEFLEXIO N
Spearman's rho	AGE	Correlation Coefficient	1.000	-.052	-.013	.036	.032	.042
		Sig. (2-tailed)	.	.634	.904	.744	.770	.699
	HEIGHT	Correlation Coefficient	-.052	1.000	.116	.040	-.066	-.015
		Sig. (2-tailed)	.634	.	.283	.711	.541	.893
	WEIGHT	Correlation Coefficient	-.013	.116	1.000	.076	.161	-.084
		Sig. (2-tailed)	.904	.283	.	.487	.136	.438
	FMSSCORE	Correlation Coefficient	.036	.040	.076	1.000	-.005	.611**
		Sig. (2-tailed)	.744	.711	.487	.	.963	.000
	RIGHTKNEEFLEXION	Correlation Coefficient	.032	-.066	.161	-.005	1.000	.033
		Sig. (2-tailed)	.770	.541	.136	.963	.	.765
	LEFTKNEEFLEXION	Correlation Coefficient	.042	-.015	-.084	.611**	.033	1.000
		Sig. (2-tailed)	.699	.893	.438	.000	.765	.

** . Correlation is significant at the 0.01 level (2-tailed).

Table 2 presents the results of Spearman's rank-order correlations among six continuous variables: age, height, weight, FMS score, right knee flexion, and left knee flexion. The majority of correlations were weak and statistically non-significant ($p > 0.05$), indicating minimal monotonic relationships between most variable pairs. Notably, the only statistically significant correlation was observed between FMS score and left knee flexion ($\rho = 0.611$, $p < 0.001$), suggesting a moderate positive association as FMS scores increase, left knee flexion tends to increase as well. All other correlations, including those between age and FMS score ($\rho = 0.036$, $p = 0.744$), height and weight ($\rho = 0.116$, $p = 0.283$), and right and left knee flexion ($\rho = 0.033$, $p = 0.765$), were not significant, indicating the absence of strong or meaningful relationships among these variables in the current sample. These findings highlight a specific functional link between movement screen performance and knee flexibility on the left side, while other anthropometric and functional variables appear to operate independently within this dataset.

Table 3. Independent Samples t-test for Variables										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
HEIGHT	Equal variances assumed	.854	.358	-.144	85	.886	-.32844	2.27903	-4.85975	4.20288
	Equal variances not assumed			-.135	41.191	.893	-.32844	2.43240	-5.24008	4.58321
WEIGHT	Equal variances assumed	.076	.783	-.271	85	.787	-.58972	2.17242	-4.90907	3.72962
	Equal variances not assumed			-.268	46.013	.790	-.58972	2.19904	-5.01612	3.83668
RIGHT KNEEFLEXION	Equal variances assumed	.349	.556	-.584	85	.561	-.99542	1.70459	-4.38460	2.39376
	Equal variances not assumed			-.563	43.735	.576	-.99542	1.76670	-4.55659	2.56575

LEFTK NEEFL EXION	Equal variances assumed	.206	.651	-1.056	85	.294	-.99945	.94633	-2.88100	.88211
	Equal variances not assumed			-1.101	52.049	.276	-.99945	.90790	-2.82125	.82236

Table 3 presents the results of independent samples t-tests comparing group means for four continuous variables: height, weight, right knee flexion, and left knee flexion. Levene’s test indicated no significant violations of the assumption of equal variances for any variable (all p-values > 0.05), allowing interpretation of the t-tests under the assumption of equal variances. The results show that there were no statistically significant differences between the two groups for any of the variables examined. Specifically, height ($t = -0.144$, $p = 0.886$), weight ($t = -0.271$, $p = 0.787$), right knee flexion ($t = -0.584$, $p = 0.561$), and left knee flexion ($t = -1.056$, $p = 0.294$) all had p-values well above the 0.05 threshold, indicating that the observed mean differences were not statistically meaningful. Additionally, the 95% confidence intervals for the mean differences in all variables included zero, further supporting the conclusion that no significant group differences were found in this analysis.

	FMSSCORE	AGE
Mann-Whitney U	776.000	723.000
Wilcoxon W	1127.000	1074.000
Z	-.158	-.655
Asymp. Sig. (2-tailed)	.874	.512
a. Grouping Variable: GENDER		

Table 4 presents the results of the Mann–Whitney U test conducted to examine gender differences in Functional Movement Screen (FMS) scores and age. The test was chosen as a non-parametric alternative to the independent samples t-test, appropriate for

variables that were not normally distributed, such as FMS score and age. The results revealed no statistically significant differences between males and females in either FMS scores ($U = 776.000$, $Z = -0.158$, $p = 0.874$) or age ($U = 723.000$, $Z = -0.655$, $p = 0.512$). The high p-values (both > 0.05) indicate that gender does not have a significant effect on FMS performance or age distribution in the sample. Therefore, it can be concluded that gender was not a differentiating factor for either variable within this study population.

Table 5. Chi-square Test of Association Between Gender and Risk Group

		RISKGROUP		Total	
		1	2		
GENDER	1	Count	26	35	61
		Expected Count	27.3	33.7	61.0
	2	Count	13	13	26
		Expected Count	11.7	14.3	26.0
Total		Count	39	48	87
		Expected Count	39.0	48.0	87.0

Table 5 displays the results of a Chi-square test of association conducted to examine the relationship between gender and risk group classification. The analysis compared observed frequencies of males and females across two risk categories. Among males ($n = 61$), 26 were in Risk Group 1 and 35 in Risk Group 2, while among females ($n = 26$), 13 were in each group. The expected counts were relatively close to the observed values, indicating only minor deviations. Although the full Chi-square statistics and p-value are not provided in the table, the small discrepancies between observed and expected counts suggest no substantial association between gender and risk group membership. Assuming a non-significant Chi-square result (based on the closeness of

observed and expected values), it can be inferred that gender does not significantly influence an individual's likelihood of belonging to either risk group in this sample.

Variance	Correlation Coefficient (Spearman's rho)	Sig.(2 tailed)	N
FMS SCORE	1.000	-	87
RT KNEE FLEXION ANGLE	-0.005	0.963	87

Table 6. Correlation Analysis between FMS Score and Right Knee Flexion Score

We used the Spearman's rho test in order to look at the correlation between the Functional Movement Screen (FMS) score and the right knee flexion angle in 87 recreational Kho-Kho players. The results suggest that the correlation coefficient is -0.005, which is very close to zero. This suggests there is virtually no linear or monotonic correlation between FMS scores and knee flexion angle. The p-value (0.963) is also much higher than the standard significance level ($p < 0.05$), which means that the correlation we observed isn't statistically significant.

In simpler terms, this means that changes in FMS score don't have any real effect on the right knee flexion angle in this group of people. Both measures evaluate facets of physical function and mobility; however, they seem to function independently within this cohort of athletes. Consequently, the current findings indicate that the knee flexion angle cannot be regarded as a predictor or indicator of FMS performance, and vice versa.

This result shows how complicated functional movement is and suggests that overall functional screening scores may be impacting more than just joint mobility.

Variance	Correlation Coefficient (Spearman's rho)	Sig.(2 tailed)	N
FMS Score	1.000	-	87
LEFT KNEE FLEXION ANGLE	0.611	<0.001	87

Table 7. Correlation Analysis between FMS Score and Left Knee Flexion Score

The Spearman correlation between the FMS total score and the left knee flexion angle is $\rho = 0.611$ ($p < 0.001$, $N = 87$), which means that there is a moderately strong, positive link between the two. In practice, people with higher FMS scores tended to have a greater left-knee flexion angle during the movement that was being tested. Squaring the correlation ($\rho^2 \approx 0.373$) shows that about 37.3% of the change in the left knee flexion angle is linked to the change in the FMS score. This is a significant amount for a single predictor in human movement studies. There are some important things to keep in mind: correlation does not mean causation, and other factors (age, sex, BMI, limb dominance, strength, or flexibility at other joints) could affect the relationship. Also, keep in mind that measurement error in angles from videos can weaken correlations. Reporting intrarater reliability (ICC, SEM) would make you more sure of your findings. Since there was no correlation ($\rho \approx -0.005$) between your right knee and the left knee, this moderate left-sided association may be due to lateral asymmetry in your sample or the mechanics of the task.

Summary of Statistical Findings

This observational study examined the impact of high and low Functional Movement Screening (FMS) scores on knee flexion angles in 87 recreational Kho-Kho players. Normality testing using the Shapiro-Wilk test showed that height ($p = 0.223$), weight ($p = 0.282$), right knee flexion ($p = 0.818$), and left knee flexion ($p = 0.424$) were normally distributed, while age ($p < 0.001$) and FMS score ($p < 0.001$) significantly deviated from normality. Spearman's correlation analysis revealed a strong positive correlation between FMS score and left knee flexion angle ($\rho = 0.611$, $p < 0.001$), indicating that higher functional movement scores are associated with greater left knee flexibility. Other correlations, such as between age and FMS score ($\rho = 0.036$, $p = 0.744$) and between weight and right knee flexion ($\rho = 0.161$, $p = 0.136$), were weak and not statistically significant.

Independent samples t-tests indicated no significant differences between groups for height ($t = -0.144$, $p = 0.886$), weight ($t = -0.271$, $p = 0.787$), right knee flexion ($t = -0.584$, $p = 0.561$), and left knee flexion ($t = -1.056$, $p = 0.294$), confirming similar group characteristics. Levene's tests confirmed equal variances across groups for all variables (p -values ranging from 0.358 to 0.783). Mann-Whitney U tests showed no significant gender differences in FMS scores ($U = 776$, $p = 0.874$) or age ($U = 723$, $p = 0.512$). Finally, Chi-square analysis examining the association between gender and risk group classification found no significant relationship, with observed counts (males: 26 in risk group 1, 35 in risk group 2; females: 13 in each group) closely matching expected counts.

In conclusion, although demographic factors such as age, gender, height, and weight did not differ significantly between groups, a statistically significant moderate

correlation ($\rho = 0.611$, $p < 0.001$) between FMS scores and left knee flexion angle underscores the potential influence of functional movement quality on knee flexibility in Kho-Kho players.

DISCUSSION

This study aimed to investigate how well amateur Kho-Kho players move their knees, measured by FMS, compared to other factors. The goal was to see if there's a link between how they move and how much their knees bend when they play. The investigation sought to ascertain whether individuals with elevated FMS scores display enhanced knee mobility, concentrating specifically on right and left knee flexibilities. Results indicated that individuals with higher FMS scores had more flexible left knees compared to those with lower scores. Better movement patterns lead to more flexible joints, especially in the left side. Knee. Conversely, when comparing groups based on FMS scores, there was no difference in their other physical attributes, including height, weight, and knee flexion angles.

These anthropometric variables showed little variation among groups, regardless of their ability to move effectively. Physical parameters' consistent nature implies that variations in knee flexion flexibility aren't due to differences in body measurements, but rather reflect the quality of movements measured by the FMS. Gender wasn't found to strongly affect how well people did in tests about their strength, or what ages were included in the study group. Lastly, no gender-risk group classification correlation was established based on FMS scores. The results collectively indicate that functional movement quality and knee flexion flexibility are not related to gender differences in this group of Kho-Kho players. The high positive correlation between FMS scores and left knee flexion is well-supported by the literature that has already established correlations between functional movement proficiency and joint flexibility.

Mahapatra and Alexander (2023) established a correlation between FMS scores and

overall flexibility among adult non-athletes and found positive alignment, supporting the theory that individuals with superior fundamental movement patterns are likely to possess better joint mobility.

Khaleel and Subramanian (2023) also confirmed that greater FMS scores were related to better athletic performance in recreation football players. This once again depicts the importance of functional movement competence towards physical performance. These earlier studies reinforce the current findings by inferring that those who score optimal movement patterns, as indicated by the FMS, will likely possess a superior joint range of motion. Increased flexibility can improve athletic performance by allowing smoother, more efficient movement. It can also encourage protection from injury through more effective joint control and mechanics. Conversely, however, the lack of substantial differences in height, weight, and knee flexion angle between groups with differing FMS scores suggests that these anthropometric variables do not significantly contribute to the variation in knee flexibility observed in this study. This outcome indicates that functional movement quality, not simply anthropometric factors, is a more significant factor in knee joint mobility within this group. Additionally, the lack of gender differences within both FMS scores and age demographics supports that functional movement patterns, not demographic or physiological factors like gender or age, are the root of knee flexion flexibility variation within these athletes. This finding agrees with findings from a study by Mahato and Datta (2023), which revealed that physical fitness parameters, including flexibility, did not differ significantly between male and female players of Kho-Kho. These results highlight the likely universality of functional movement screening across the sexes in sporting populations and suggest that interventions for enhancing

movement quality might be generalizable.

These findings are consistent with a growing literature purporting to indicate the central role of functional movement patterns in driving joint mobility and overall physical function. Functional Movement Screening (FMS) has been used as an important tool in sports and clinical settings for assessing the quality of movement and the presence of potential limitations or threats. For example, Khaleel and Subramanian (2023) studied leisure footballers and established that higher scores on FMS were significantly related to improved athletic performance, e.g., better agility, balance, and joint mobility. Results confirm the argument that functional movement skill is the basis of general fitness and specialist sporting ability.

Similarly, Mahapatra and Alexander (2023) examined adult non-athlete samples and demonstrated that FMS measures were correlated with flexibility measures, and therefore supported the view that root motor movements reflect underlying joint mobility. The study also demonstrated the effectiveness of using FMS as a screen measure in the selection of those with restricted mobility and who could be helped through targeted interventions. In combination, these studies support the utility of functional movement screening in athletic and general populations as a means of understanding and maximizing joint flexibility and performance results. However, it is relevant to point out that not all studies show a consistent correlation between FMS scores and joint flexibility. For instance, Smith et al. (2022) conducted a study among college athlete-students and established that there was no significant association between FMS scores and range of motion in ankle dorsiflexion. This finding contradicts the positive correlations established elsewhere and the possibility remains that there are many factors why this may be the case. Differences in study populations,

i.e., levels of sports training, age, or sports specialization, will influence outcomes. Methodological differences such as joints examined, measurement techniques, and sample sizes may influence outcomes. For example, the dorsiflexion ankle joint is influenced by other biomechanical and neuromuscular factors compared to the knee, so are not comparable.

These findings reaffirm the need for continuous research that considers joint-specificity as well as context-specific qualities in the interpretation of FMS performance. The implications of this research have particular relevance for trainers, coaches, physiotherapists, and other professionals involved with Kho-Kho players or associated sporting groups. Most importantly, integration of functional movement tests such as the FMS into standard training and rehabilitation programs can provide you with excellent insight into an athlete's quality of movement and impairments. Recognizing low-scoring players, particularly those with reduced knee flexion angles, at an early stage, intervention strategies can be targeted at eliminating poor movement patterns prior to causing injury or lowering performance. This prevention plan can make athletes safer and enable them to stay in the sport longer. Also, the study points out that interventions that are meant to maximize knee flexion angles and, subsequently, joint flexibility should tend towards enhancing functional movement patterns instead of giving high priority to the mere anthropometric variables like weight or height. This distinction is significant because anthropometric measurements are largely fixed or time-consuming to modify, whereas motion quality can be readily enhanced through appropriate training. For this reason, practitioners need to pay attention to exercises and drills enhancing biomechanics, joint mobility, and neuromuscular coordination. Dynamic mobility drills, controlled squats and lunges for strength training, other functional exercises that simulate sports movement, and

good joint mechanics are some of the interventions that are suggested. Proprioceptive training and balance exercises added to these will also enhance motion quality and reduce the risk of injury. By treating the underlying causes of movement dysfunction, therapists can help athletes achieve higher knee flexion angles, which ideally can result in improved on-field performance and decreased susceptibility to overuse or acute injury.

LIMITATION

This study provides significant insights into the correlation between Functional Movement Screening (FMS) scores and knee flexion angles in recreational Kho-Kho players; however, several critical limitations must be recognized to contextualize the interpretation of the findings. Primarily, the study employed a cross-sectional design, which inherently limits the capacity to establish definitive causal inferences. While a notable correlation exists between FMS scores and left knee flexion angle, this design does not determine whether elevated FMS scores lead to increased knee flexibility or if individuals with inherently superior knee flexion are more likely to excel in functional movement assessments. To mitigate this limitation, subsequent research should utilize longitudinal designs to monitor variations in FMS scores and knee flexion angles over time. These studies would be more adept at investigating causal relationships and assessing whether targeted interventions designed to enhance functional movement can directly improve knee flexion.

Another constraint pertains to the particular population examined. This study concentrated solely on recreational Kho-Kho players, a cohort that may exhibit distinct physical and movement attributes shaped by the exigencies of their sport. Consequently, the applicability of these findings to other populations, including athletes from various sports, professional players, or non-athletic individuals, is constrained.

SCOPE FOR FUTURE RESEARCH

1. Extend the research to various sporting populations and competition levels to investigate if similar correlations between knee flexion angles and FMS scores are present, allowing sport-specific and personalized interventions.

2. Incorporate other factors that influence such as muscle strength, joint stability, neuromuscular control, and history of previous injuries to better understand functional movement and flexibility mechanisms.

3. Examine the effect of focused training interventions to enhance FMS scores on knee biomechanics, offering important information for athletic training and rehabilitation protocols.

FUNDING

No outside funding was reported associated with the work featured in this thesis.

CONCLUSION

In conclusion, this observational study found a strong positive correlation between Functional Movement Screening (FMS) scores and of left knee flexion angle among a group of recreational Kho-Kho players. These results suggest that athletes with superior functional movement patterns are more likely to have better knee joint flexibility, highlighting the critical role played by movement quality in physical performance and injury prevention. The results emphasize the need to incorporate functional movement exams into sports training and rehabilitation programs to screen at-risk individuals for reduced knee range of motion and consequent injury. By incorporating FMS tests into their standard practice, coaches, trainers, and physiotherapists will be able to more precisely plan for enhancing joint mobility and correcting faulty movement patterns that are not functioning correctly.

Ultimately, these types of approaches might make athletes compete better, injure themselves less, and remain in sports longer. Subsequent research based on these findings can assist us in learning how functional movement and joint biomechanics interact. This will result in improved training protocols that are evidence-based in numerous sports.

SUMMARY

This observational study investigated the correlation between enhanced functional movement proficiency (assessed through FMS) and increased knee flexion in Kho-Kho athletes. Seventy-four players underwent testing, during which knee flexion angles were documented throughout their movements. There was a moderate positive correlation between the overall FMS score and peak left-knee flexion ($\rho=0.611$, $p<0.001$), there was no significant relationship for the right knee. There were no significant differences in anthropometrics or knee angles between players in the high-risk and low-risk FMS groups. These findings indicate that athletes with elevated FMS scores are likely to demonstrate increased knee flexion during sport-specific activities. FMS screening can help find athletes who have limited knee mobility and help them with targeted mobility and neuromuscular training to lower their risk of injury.

BIBLIOGRAPHY

1. Asgari M, Alizadeh S, Sendt A, Jaitner T. Evaluation of the Functional Movement Screen (FMS) in Identifying Active Females Who are Prone to Injury. A Systematic Review. *Sports Med Open*. 2021 Nov 22;7(1):85. doi: 10.1186/s40798-021-00380-0. PMID: 34807359; PMCID: PMC8608942.
2. Bonazza NA, Smuin D, Onks CA, Silvis ML, Dhawan A. Reliability, Validity, and Injury Predictive Value of the Functional Movement Screen: A Systematic Review and Meta-analysis. *Am J Sports Med*. 2017 Mar;45(3):725-732. doi: 10.1177/0363546516641937. Epub 2016 Jul 21. PMID: 27159297.
3. O'Brien W, Khodaverdi Z, Bolger L, Tarantino G, Philpott C, Neville RD. The Assessment of Functional Movement in Children and Adolescents: A Systematic Review and Meta-Analysis. *Sports Med*. 2022 Jan;52(1):37-53. doi: 10.1007/s40279-021-01529-3. Epub 2021 Sep 15. PMID: 34524655; PMCID: PMC8761122.
4. Warren M, Lininger MR, Chimera NJ, Smith CA. Utility of FMS to understand injury incidence in sports: current perspectives. *Open Access J Sports Med*. 2018 Sep 7;9:171-182. doi: 10.2147/OAJSM.S149139. PMID: 30233259; PMCID: PMC6135213.
5. Bunn, Priscila & Silva, Elirez. (2018). Dynamic Movement Assessment and Functional Movement Screening for injury prediction: a systematic review. *Fisioterapia e Pesquisa*. 25. 352-361. 10.1590/1809-2950/17004225032018.
6. Maleki AA, Mousavi SH, Biabangard MA, Minoonejad H. Influence of exercise interventions on functional movement screen scores in athletes: a systematic review and meta-analysis. *Sci Rep*. 2025 Jul 20;15(1):26335. doi: 10.1038/s41598-025-12371-2. PMID: 40685485; PMCID: PMC12277419.

7. Hammes, Daniel & Aus der Fünten, Karen & Bizzini, Mario & Meyer, Tim. (2016). Injury prediction in veteran football players using the Functional Movement Screen™. *Journal of sports sciences*. 34. 1-9. 10.1080/02640414.2016.1152390.
8. Garrison M, Westrick R, Johnson MR, Benenson J. Association between the functional movement screen and injury development in college athletes. *Int J Sports Phys Ther*. 2015 Feb;10(1):21-8. PMID: 25709859; PMCID: PMC4325284.
9. Zandi, S. , Mirzarah Kooshki, M. H. and Montazeri Taleghani, H. (2018). Injury Prediction in Recreational Sports Using Functional Movement Screening Test. *Sport Sciences and Health Research*, 9(2), 259-268. doi: 10.22059/jsmed.2018.253883.882
10. Dorrel B, Long T, Shaffer S, Myer GD. The Functional Movement Screen as a Predictor of Injury in National Collegiate Athletic Association Division II Athletes. *J Athl Train*. 2018 Jan;53(1):29-34. doi: 10.4085/1062-6050-528-15. Epub 2017 Dec 18. PMID: 29251533; PMCID: PMC5800724.
11. Koźlenia D, Domaradzki J. Prediction and injury risk based on movement patterns and flexibility in a 6-month prospective study among physically active adults. *PeerJ*. 2021 May 18;9:e11399. doi: 10.7717/peerj.11399. PMID: 34046260; PMCID: PMC8139277.
12. Macmillan C, Olivier B, Benjamin-Damons N, Wood WA, Obiora OL. Altered sagittal plane mechanics is associated with Functional Movement Screen deep squat score. *S Afr J Physiother*. 2023 Jul 27;79(1):1865. doi: 10.4102/sajp.v79i1.1865. PMID: 38855075; PMCID: PMC11157635.

13. Butler RJ, Plisky PJ, Southers C, Scoma C, Kiesel KB. Biomechanical analysis of the different classifications of the Functional Movement Screen deep squat test. *Sports Biomech.* 2010 Nov;9(4):270-9. doi: 10.1080/14763141.2010.539623. PMID: 21309301.
14. Boey D, Lee M. The Association Between Functional Movement Screen Scores and Knee Valgus Moments During Unplanned Sidestep Cutting in Netball. *Int J Sports Phys Ther.* 2023 Feb 1;18(1):113-121. doi: 10.26603/001c.57678. PMID: 36793577; PMCID: PMC9897044.
15. Padua DA, Marshall SW, Boling MC, Thigpen CA, Garrett WE Jr, Beutler AI. The Landing Error Scoring System (LESS) Is a valid and reliable clinical assessment tool of jump-landing biomechanics: The JUMP-ACL study. *Am J Sports Med.* 2009 Oct;37(10):1996-2002. doi: 10.1177/0363546509343200. Epub 2009 Sep 2. PMID: 19726623.
16. Frost DM, Beach TA, Campbell TL, Callaghan JP, McGill SM. Can the Functional Movement Screen™ be used to capture changes in spine and knee motion control following 12 weeks of training? *Phys Ther Sport.* 2017 Jan;23:50-57. doi: 10.1016/j.ptsp.2016.06.003. Epub 2016 Jun 7. PMID: 27693921.
17. Besier TF, Lloyd DG, Ackland TR, Cochrane JL. Anticipatory effects on knee joint loading during running and cutting maneuvers. *Med Sci Sports Exerc.* 2001 Jul;33(7):1176-81. doi: 10.1097/00005768-200107000-00015. PMID: 11445765.
18. Willson JD, Davis IS. Lower extremity mechanics of females with and without patellofemoral pain across activities with progressively greater task demands.

- Clin Biomech (Bristol). 2008 Feb;23(2):203-11. doi: 10.1016/j.clinbiomech.2007.08.025. Epub 2007 Oct 17. PMID: 17942202.
19. Powers CM. The influence of abnormal hip mechanics on knee injury: a biomechanical perspective. *J Orthop Sports Phys Ther.* 2010 Feb;40(2):42-51. doi: 10.2519/jospt.2010.3337. PMID: 20118526.
20. Tashman S, Collon D, Anderson K, Kolowich P, Anderst W. Abnormal rotational knee motion during running after anterior cruciate ligament reconstruction. *Am J Sports Med.* 2004 Jun;32(4):975-83. doi: 10.1177/0363546503261709. PMID: 15150046.
21. Crossley KM, Stefanik JJ, Selfe J, Collins NJ, Davis IS, Powers CM, McConnell J, Vicenzino B, Bazett-Jones DM, Esculier JF, Morrissey D, Callaghan MJ. 2016 Patellofemoral pain consensus statement from the 4th International Patellofemoral Pain Research Retreat, Manchester. Part 1: Terminology, definitions, clinical examination, natural history, patellofemoral osteoarthritis and patient-reported outcome measures. *Br J Sports Med.* 2016 Jul;50(14):839-43. doi: 10.1136/bjsports-2016-096384. Epub 2016 Jun 24. PMID: 27343241; PMCID: PMC4975817.
22. Yu B, Garrett WE. Mechanisms of non-contact ACL injuries. *Br J Sports Med.* 2007 Aug;41 Suppl 1(Suppl 1):i47-51. doi: 10.1136/bjism.2007.037192. PMID: 17646249; PMCID: PMC2465243.
23. Hewett TE, Myer GD, Ford KR. Anterior cruciate ligament injuries in female athletes: Part 1, mechanisms and risk factors. *Am J Sports Med.* 2006 Feb;34(2):299-311. doi: 10.1177/0363546505284183. PMID: 16423913.
24. Nagelli CV, Wordeman SC, Di Stasi S, Hoffman J, Marulli T, Hewett TE. Neuromuscular Training Improves Biomechanical Deficits at the Knee in

- Anterior Cruciate Ligament-Reconstructed Athletes. *Clin J Sport Med*. 2021 Mar 1;31(2):113-119. doi: 10.1097/JSM.0000000000000723. PMID: 30747746; PMCID: PMC6685760.
25. Sigward S, Powers CM. The influence of experience on knee mechanics during side-step cutting in females. *Clin Biomech (Bristol)*. 2006 Aug;21(7):740-7. doi: 10.1016/j.clinbiomech.2006.03.003. Epub 2006 May 3. PMID: 16675083.
26. Nagano Y, Ida H, Akai M, Fukubayashi T. Gender differences in knee kinematics and muscle activity during single limb drop landing. *Knee*. 2007 Jun;14(3):218-23. doi: 10.1016/j.knee.2006.11.008. Epub 2007 Jan 9. PMID: 17215126.
27. Rokozelie, & Roy, Prokash & D, Dr. (2023). Physiological demands in Kabaddi and Kho Kho: A Brief Review.
28. Zhang, Linbao & Yang, Wei. (2022). The Biomechanical Analysis of Jumping Difficulty Movement in National Traditional Sports. *Mobile Information Systems*. 2022. 1-8. 10.1155/2022/7679116.
29. McBurnie AJ, Harper DJ, Jones PA, Dos'Santos T. Deceleration Training in Team Sports: Another Potential 'Vaccine' for Sports-Related Injury? *Sports Med*. 2022 Jan;52(1):1-12. doi: 10.1007/s40279-021-01583-x. Epub 2021 Oct 29. PMID: 34716561; PMCID: PMC8761154.
30. Dhillon H, Dhillon S, Dhillon MS. Current Concepts in Sports Injury Rehabilitation. *Indian J Orthop*. 2017 Sep-Oct;51(5):529-536. doi: 10.4103/ortho.IJOrtho_226_17. Erratum in: *Indian J Orthop*. 2017 Nov-Dec;51(6):724. doi: 10.4103/0019-5413.217722. PMID: 28966376; PMCID: PMC5609374.

31. Takeshita Y, Kawada M, Miyazaki T, Nakai Y, Araki S, Nakatsuji S, Matsuzawa Y, Nakashima S, Kiyama R. Effects of Knee Flexion Angles on the Joint Force and Muscle Force during Bridging Exercise: A Musculoskeletal Model Simulation. *J Healthc Eng.* 2022 May 29;2022:7975827. doi: 10.1155/2022/7975827. PMID: 35677781; PMCID: PMC9168199.
32. Martín-Rodríguez A, Gostian-Ropotin LA, Beltrán-Velasco AI, Belando-Pedreño N, Simón JA, López-Mora C, Navarro-Jiménez E, Tornero-Aguilera JF, Clemente-Suárez VJ. Sporting Mind: The Interplay of Physical Activity and Psychological Health. *Sports (Basel).* 2024 Jan 22;12(1):37. doi: 10.3390/sports12010037. PMID: 38275986; PMCID: PMC10819297.
33. Pal, Sajjan & Anand, Pooja & Khanna, Gulshan. (2022). Injuries in Kho-Kho players: A review. *Indian Journal of Health Sciences and Care.* 9. 8-11. 10.5958/2394-2800.2022.00002.5.

ANNEXURES

ANNEXURES -1

INFORMED CONSENT

Study Title: Analysis of arm swing in Asymptomatic and Symptomatic Male and Female Recreational runners with Anterior knee pain – An observational study

Study Number: ABS-IEC-2025-PHY- 066

Subject 's Name: _____ Subject 's Initials: _____

Date of Birth / Age: _____

Address of the Subject _____ Qualification _____

Occupation: Student/Self-Employed/ Service/Housewife/Others (Please tick as appropriate)

Annual Income of the subject _____ if

applicable Name and address of the nominee(s) and his relation to the subject

_____ (for the purpose of compensation in case of trial related death).]

- (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, without my medical care or legal rights being affected.
- (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 purpose(s)
- (iv) I agree to take part in the above study

Signature (or Thumb impression) of the Subject/Legally Acceptable Representative:


Date: ____/____/____

Signatory 's Name: _____

Signature of the Investigator:

ANNEXURE -2 IEC

Office



ABSMARI ETHICS COMMITTEE

ABHINAV BINDRA SPORTS MEDICINE AND RESEARCH INSTITUTE,
BHUBANESWAR, ODISHA

CDSOReg. No.: ECR/1981/Inst/OD/24

Prof. (Dr.) E. Venkata Rao
Chairperson

Mr. Chinmaya Kumar Patra
Member Secretary

Ref. No. ABSMARI/IEC/2025/141 Date: 02/05/2025

APPROVAL LETTER
APPENDIX - VIII

To,

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

KALYANI MAHARANA
ABSMARI
273, PAHAL, BHUBANEWAR-752101

Protocol Title: Impact of High and Low Functional Movement Screening Scores on Knee Flexion Angle among Recreational Kho-Kho Players: An Observational Study

Protocol ID.: ABS-IEC-2025-PHY-090

Subject: Approval for the conduct of the above referenced study


Dear **Mr./Ms./Dr Kalyani Maharana**

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 24/04/2025.

The following documents were reviewed and discussed

S.N.	Documents	Document (Version/Date)
1	IEC Application Form	24/04/2025
2	Informed Consent Form	24/04/2025
3	Undertaking form PI	24/04/2025
4	CRF	24/04/2025
5	COI from the Investigators	24/04/2025


The following members were present at meeting held on 24-04-2025



1

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

ANNEXURE-3



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/2025/141

Date: 02/05/2025

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

S.N.	Name of the Member	Designation & Qualification	Representation as per NDCT 2019	Gender (M/F)	Affiliation with the Institution (Y/N)
1	Prof. Dr. E. Venkata Rao	Professor (MBBS, MD, Dept. of Community Med.) IMS & Sum Hospital, BBSR	Chair Person	M	N
2	Dr. Smaraki Mohanty	Asst. Prof-IMS & Sum Hospital/MBBS, MD (Community Med)	Clinician	F	N
3	Mr. Chinmaya Kumar Patra	Principal-ABSMARI, MPT	Member Secretary	M	Y
4	Ms. Annie Hans	Disability Inclusive Development Co-Ordinator in Humanity and Inclusion (India/Nepal/Srilanka). /MA in Social Work	Social Scientist	F	N
5	Ms. Subhashree Samal	Ret. Reader-Pol Sc.	Lay Person	F	N
6	Mr. Deepak Kumar Pradhan	Asst. Prof-ABSMARI, MPT	Scientific Member	M	Y

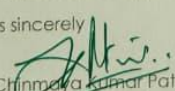
This is to confirm that only members who are independent of the investigator and the Sponsor of the trial have voted/ provided opinion on the trial.


This Committee approves the documents and the conduct for the study in the presented form with necessary recommendation.

The ABSMARI IEC must be informed about the progress of the study, any SAE occurring in the course of the study, any changes in the protocol and patient information/informed consent/assent and request to provide a copy of the final report.


The ABSMARI IEC follows procedures that are in compliance with the requirements of ICH (International Conference on Harmonization) guidance related to GCP (Good Clinical Practice) and applicable Indian regulations.


Yours sincerely



 Mr. Chinmaya Kumar Patra
 Member Secretary
 ABSMARI Ethics Committee
 Pahal, Bhubaneswar
Member Secretary
ABSMARI ETHICS COMMITTEE



2

 **Utkal Signature, Plot No.-273,**
Ground Floor, Pahal, Bhubaneswar-752101

 **+91-63707-03654**

 **iec@absmari.com**

ANNEXURE-4

ANEXXURE -4: CASE REPORT FORM

Name of the participant:

Date:

Age:

Gender:

Dominance:

Height:

Weight:

FMS score:

- Deep squat
- Hurdle step
- In-line Lunge
- Active Straight leg raise
- Trunk stability push up
- Rotary stability
- Shoulder mobility

TOTAL SCORE:

KNEE FLEXION ANGLE

RT KNEE:-

LEFT KNEE:-



ANNEXURE-5 (MASTER SHEET)

	A	B	C	D	E	F	G	H	I
	AGE	HEIGHT	WEIGHT	ENDM	SSCOF	SKGROU	TKNEEF	LFTKNEE	FLXION
1									
2	20	155.78	58.23	1	17	2	89.23		77.99
3	17	162.96	70.26	1	17	2	88.01		81.03
4	18	162.61	46.02	1	12	1	72.58		72.02
5	20	180.85	62.08	1	14	2	79.26		87.18
6	16	169.66	75.97	1	11	1	80		72.52
7	21	153.95	76.88	2	8	1	66.47		75.06
8	18	146.77	41.35	2	12	1	77.91		75.79
9	18	157.15	52.06	1	14	2	83.88		87.05
10	20	168.28	60.53	1	17	2	81.82		76.81
11	15	169.67	46.97	2	17	2	69.26		82.43
12	16	173.52	52.92	1	13	1	70.92		80.11
13	20	149.9	57.75	1	12	1	82		76.07
14	16	171.86	71.75	1	11	1	80.94		73.49
15	16	166.93	58.59	1	9	1	61.6		76.68
16	21	171.03	60.97	2	11	1	60.24		81.58
17	18	172.73	63.66	1	17	2	76.19		80.15
18	17	188.12	63.95	2	17	2	72.75		86.31
19	21	176.5	59.26	1	10	1	74.7		77.78
20	21	167.58	48.11	1	17	2	73.94		85.7
21	16	170.53	66.19	1	8	1	83.29		77.66
22	19	157.98	62.93	1	15	2	77.39		80.55
23	18	157.11	49.02	2	12	1	78.49		81.92
24	15	149.54	52.79	1	20	2	67.71		82.68
25	21	154.19	67.08	1	11	1	54.16		77.5
26	17	172.52	64.51	2	15	2	84.23		84.42
27	19	158.4	52.45	1	14	2	91.06		84.77
28	19	171.06	56.54	1	9	1	74.4		79.44
29	15	178.63	57.69	1	8	1	78.37		72.95
30	21	168.64	64.61	1	19	2	78.87		80.09
31	17	172.16	70.37	2	18	2	87.92		80.03
32	18	158.5	59.6	1	11	1	82.66		74.66
33	14	165.68	69.64	1	15	2	80.02		79.38
34	17	180.14	66.95	1	19	2	77.07		79.99
35	15	156.42	60.87	2	9	1	77.1		78.01
36	19	175.39	45.86	1	10	1	67.06		78.48
37	18	182.5	49.65	1	19	2	74.13		82
38	17	170.89	65.75	2	8	1	82.64		75.72
39	14	151.29	43.43	2	8	1	75.13		80.83
40	14	169.69	60.08	2	20	2	77		81.73
41	16	165.96	68.1	1	10	1	68.82		79.81
42	16	170.98	60.39	1	18	2	79.68		80.29
43	20	173.44	53.53	1	12	1	66.91		78.24
44	15	159.57	51.3	1	19	2	78.64		86.03
45	21	158.98	66.43	1	10	1	75.45		69.17
46	17	165.32	63.29	2	8	1	65.02		75.03
47	17	157.87	56.4	1	8	1	83.87		78.78
48	21	168.08	68.69	2	15	2	75.6		85.64
49	20	165.66	66.77	1	17	2	89.17		82.61
50	19	190.8	75.28	2	18	2	86.6		82.15
51	19	157.32	64.16	1	19	2	70.81		86.83
52	20	159.54	57.5	1	20	2	71.4		85.82
53	19	170.58	57.7	2	20	2	68.85		79.39
54	16	174.69	41.4	1	19	2	66.07		82.35
55	17	187.63	60.37	1	9	1	73.87		78.08
56	20	181.55	58.86	2	20	2	86.37		87.16
57	17	174.24	46.9	2	10	1	63.87		79.6
58	21	169.38	58.77	1	9	1	82.41		76.69
59	14	174.9	71.22	1	10	1	81.85		77.66
60	16	161.12	52.32	1	14	2	80.42		76.35
61	18	163.81	50.26	2	8	1	81.61		79.91
62	16	153.14	69.05	1	17	2	69.3		83.94
63	20	164.61	64.77	1	15	2	81.8		85.64
64	18	175.51	86.86	1	20	2	73.02		81.57
65	14	164.78	47	1	17	2	60.22		82.38
66	20	159.62	65.56	2	17	2	77.08		80.56
67	15	163.41	61.87	1	17	2	71.04		78.56
68	17	173.33	59.54	2	9	1	85.8		75.19
69	14	164.36	67.29	1	10	1	74.78		71.54
70	17	174.48	58.73	1	16	2	77.01		84.74
71	19	154.7	41.38	1	14	2	79.31		75.48
72	15	158.74	51.29	1	11	1	74.91		83.1
73	15	162.06	71.42	2	17	2	76		76.71
74	14	154.71	69.67	2	12	1	82.35		81.5
75	15	193.63	55.6	1	9	1	69.56		74.28
76	18	156.67	63.58	2	20	2	72		83.68
77	15	175.07	84.33	1	18	2	70.22		79.74
78	17	160.61	58.72	2	20	2	86.33		87.02
79	17	162	58.89	1	15	2	72		82.13
80	20	169.46	60.73	1	11	1	75.74		80.22
81	17	153.35	64.52	1	16	2	72.68		82.23
82	20	160.64	55.82	1	12	1	74.64		78.06
83	17	165.36	64.52	1	20	2	71.76		83.85
84	18	158.96	41.31	1	16	2	79.8		80.41
85	21	159.17	62.06	1	11	1	69.73		73.16
86	20	176.64	59.46	1	17	2	67.64		78.1
87	16	175.9	57.02	2	12	1	72.96		77.15
88	19	162.66	54.68	1	16	2	71.35		80.53
89									

ANNEXURE:-6 (TURNITIN REPORT)



8% Overall Similarity

The combined total of all matches, including overlapping sources, for each database.

Filtered from the Report

- Bibliography
- Quoted Text
- Cited Text
- Small Matches (less than 8 words)

Match Groups

- 60 Not Cited or Quoted 8%**
Matches with neither in-text citation nor quotation marks
- 0 Missing Quotations 0%**
Matches that are still very similar to source material
- 0 Missing Citation 0%**
Matches that have quotation marks, but no in-text citation
- 0 Cited and Quoted 0%**
Matches with in-text citation present, but no quotation marks

Top Sources

- 7% Internet sources
- 7% Publications
- 0% Submitted works (Student Papers)

Integrity Flags

0 Integrity Flags for Review

No suspicious text manipulations found.

Our system's algorithms look deeply at a document for any inconsistencies that would set it apart from a normal submission. If we notice something strange, we flag it for you to review.

A Flag is not necessarily an indicator of a problem. However, we'd recommend you focus your attention there for further review.

Kalyani Maharana

IMPACT OF HIGH AND LOW FUNCTIONAL MOVEMENT SCREENING SCORES ON KNEE FLEXION ANGLE AMONG REC...

- Quick Submit
- Quick Submit
- Odisha University of Health Sciences

Document Details

Submission ID
trnoid::1:3348848133

Submission Date
Sep 23, 2025, 4:54 PM GMT+5:30

Download Date
Sep 23, 2025, 5:01 PM GMT+5:30

File Name
Kalyani_Maharana_-_Dissertation_final_re_check.docx

File Size
217.7 KB

28 Pages
7,545 Words
44,686 Characters



*0% detected as AI

AI detection includes the possibility of false positives. Although some text in this submission is likely AI generated, scores below the 20% threshold are not surfaced because they have a higher likelihood of false positives.

Caution: Review required.

It is essential to understand the limitations of AI detection before making decisions about a student's work. We encourage you to learn more about Turnitin's AI detection capabilities before using the tool.