Effect of Quadrupedal Movement Training on Flexibility

& Hitting Accuracy on Amateur Lawn Tennis Athletes: A Randomized Controlled Trial.

By

ANUSHKA

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In

SPORTS PHYSIOTHERAPY

Under the Guidance of

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2023-2025

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LIST OF ABBREVIATIONS USED

Abbreviation	Full Form
QMT	Quadrupedal Movement Training
HATT	Hitting Accuracy Tennis Test
GIRD	Glenohumeral Internal Rotation Deficit
USTA	United States Tennis Association
SPSS	Statistical Package for the Social Sciences
ABSMARI	Abhinav Bindra Sports Medicine & Research Institute
ICC	Intraclass Correlation Coefficient
FHAT	Forehand Cross Court
FHCC	Forehand Cross Court
FHULT	Forehand Down the Line
TWU	Traditional Warm-Up
DWU	Dynamic Warm-Up
CMS	Core Mobility Series
NMDS	Neuromuscular Development Sequence

RCT	Randomized Controlled Trial
ROM	Range of Motion
HS	Highly Significant ($p<0.001$)

ABSTRACT

Background: The present study will assess the effectiveness of Quadrupedal Movement Training (QMT) protocols in increasing the range of motion and joint flexibility parameters among recreational tennis players compared with the traditional conditioning procedures.

Objective: To establish the particular effects of QMT interventions on the domains of flexibility that are of critical importance in the performance of tennis and to determine whether such training has statistically significant and clinically meaningful effects over and above traditional training programs.

Methods: The randomized controlled study design is used in 30 amateur tennis players, which are randomly assigned into experimental and control cohort. The experimental and control groups had to undergo four weeks of organized QMT protocol and the control continued with the training regimens they were accustomed to respectively. Flexibility tests like; shoulder range of motion tests, and sit and reach tests were conducted at both baseline time and post intervention time. The SPSS software was used to perform statistical analysis using paired t-tests and nonparametric within and between group analysis tests.

Results: The experimental group showed a significant improvement in the different parameters of the flexibility ($p<0.001$) with moderate to large effect sizes, which are not only statistically significant but also practical. The measures of shoulder mobility did not show much improvement in the control group. The inter-group comparisons showed higher improvement in bilateral shoulder flexibility and sit-and-reach in the QMT group compared to the controls and it may indicate the efficiency of the specific training in the process of acquiring relevant joint mobility in tennis.

Interpretation & Conclusions: Quadrupedal Movement Training has been more effective in its effectiveness compared to the conventional training techniques in the attainment of flexibility and joint mobility among amateur tennis players. Such findings make the application of QMT techniques in sports training programs in the quest to attain the optimal performances a rational choice.

Keywords: Quadrupedal Movement Training, range of motion, joint flexibility, tennis conditioning, randomized controlled study, sports performance enhancement

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INTRODUCTION

Modern tennis game has been intensified to one of the most difficult games that require good physical training, technical precision and strategy in playing the game. The modern tennis play is characterized by fast movement in different directions, immediate acceleration and deceleration patterns, complex rotational mechanics and extended periods of maximum performance to play matches. In this superior grid of performance determinants, there are always two structural elements that are presented to be the dominant success factors accuracy precision hitting and range of motion. Research core: Fundamental stroke mechanisms and injury prevention, precise ball hitting is the primary feature of both functional point building and the application in the competitive tennis environment which is facilitated by a functional joint mobility [1][2][3][4][5][6][7][8][9].

The classical conditioning tennis models have been largely concerned with individual programs of isolated strength training, linear power-generating activities, and on-court repetitive training of the technical exercises. As much as these old methodologies can provide some level of performance improvement, it will be unable to recognize the integrated whole body movement patterns, which determine the production of tennis stroke and movement around the court. Moreover, the starting of tennis players may also be insufficiently fitted in the area of complete training equipment and technical coaching experience that undermines both the physical and technical progress within the abilities. This was a serious performance gap weakness that can be handled through the application of recent and accessible training approaches that are capable of targeting multiple performance attributes[10][11][12] concurrently.

Quadrupedal movement training (QMT) is one of the new paradigms in sport conditioning who follow the example of the simplest human locomotor patterns evident in the initial stages of development. This type of exercise incorporates a number of animal motion models that include bear crawls, ape reaches, lizard walks, and crab movements; this combination of moves engages the neuromuscular system in the four-limb support postures in dynamic weight-bearing exercises. QMT distinguishing characteristics are that it demands greater demands of the core stabilization, increased inter-limb coordination requirements, greater proprioceptive feedback, and greater functional range of motion development of multiple joint systems simultaneously[13][14][15][16][17][18][19][20][21].

On-going scientific studies have provided positive outcomes after QMT interventions in different groups of people. According to a study by Buxton and colleagues, there were significant improvements in the gains in functional movement screening scores, muscular strength scores, and range of motion scores after an eight-week QMT program. Increased joint repositioning accuracy and signs of cognitive functioning were also reported after quadrupedal training interventions as reported by Matthews and colleagues. These findings suggest that QMT has the potential to provide highly neuromuscular adaptations not only surpassing standard training benefits, but also providing superior transfer to sport-specific performance requirements[22][23].

The biomechanical demands of production of tennis strokes are complex patterns including of kinetic chains; generation of lower extremity ground reaction force, core rotation and stability, and ultimate precision of upper extremity stance and racket ball velocity. It is a complex movement of motion which demands maximum flexibility of

posterior kinetic chain muscles including hip flexor, hamstring, thoracic spine and muscle of the shoulder girdle. The same joint positioning has also been found to be the foundation of accuracy of striking, coherent time coordination and stable postural control of variable loads and fatigue conditions [24] [25] [26] [27] [28] [29] [30] [31] [32].

The quadrupedal locomotion patterns are high and thus, they in themselves put the neuromuscular systems that are involved in producing tennis strokes to the test. QMT exercises are weight bearing exercises that stimulate the stability and mobility of the shoulder girdle through the activities of loaded range of movement and impose flexion and extension pattern of the hip that is typical of the tennis movement demand, and may also transfer the same to higher levels of stroke consistency and accuracy[33].

Despite growing interest in QMT applications, systematic research examining its effects on tennis-specific performance outcomes remains limited. While preliminary evidence supports QMT's capacity to enhance general flexibility and functional movement capabilities, no randomized controlled trials have specifically investigated whether these improvements translate to meaningful gains in tennis hitting accuracy among amateur athletes. This research gap represents a significant limitation in the current evidence base and hinders the development of evidence-based training recommendations for tennis conditioning.

Amateur lawn tennis participants face unique challenges that distinguish them from elite or professional players. These athletes typically maintain full-time occupational commitments, possess limited access to specialized coaching and training facilities,

and often rely on self-directed practice sessions for skill development. Consequently, amateur players require time-efficient, cost-effective training interventions that can be implemented with minimal equipment and supervision while providing maximal performance benefits. Quadrupedal movement training appears ideally suited to address these constraints, as it requires no specialized equipment, can be performed in limited space, and targets multiple fitness components simultaneously.[39][40][41]

The theoretical foundation for QMT's potential effectiveness in tennis training rests upon several key principles. First, the multi-planar loading characteristics of quadrupedal exercises may enhance flexibility through dynamic stretching mechanisms that exceed the range of motion gains achieved through traditional static stretching protocols. Second, the proprioceptive demands of maintaining four-point support during dynamic movements may improve joint position sense and movement quality, potentially enhancing stroke consistency and accuracy. Third, the integrated nature of QMT exercises may promote superior neuromuscular coordination and timing precision compared to isolated training approaches.[42][43][44][45][46][47][48][49][50]

Current tennis stroke biomechanics research has identified several critical flexibility requirements for optimal performance. Flexibility of the hip flexors is a critical component to effective stride placement with groundstroke preparation, whereas hamstring flexibility is vital to adequate follow-through mechanics and avoiding injury. Thoracic spine rotation capacity directly enhances stroke power generation and ball placement accuracy, particularly when hitting cross-court and down-the-line strokes. Shoulder girdle mobility and stability are the primary for serve production

and efficiency of overhead strokes. These specific demands for flexibility are highly consistent with the movement requirements imposed by quadrupedal training drills.

Tennis stroke accuracy is a multifaceted skill that necessitates spatial accuracy, temporal consistency, and adaptive control between conditions. Accuracy gain has been demonstrated in many studies to result from enhanced proprioceptive perception, increased joint stability, and better motor control patterns. It is possible that neuromuscular adaptations caused by QMT could be the cause of each of these factors due to its emphasis on whole-body integration, dynamic stability challenges, and proprioceptive stimulation.

This existing research bridges these gaps in research through conducting a randomized controlled trial plan to investigate the influence of quadruped movement training on both flexibility and accuracy of hits leads to novice grass tennis players. This study represents the first in-depth review of QMT's applications to tennis provides essential evidence for constructing evidence-based training programs.

AIM OF THE STUDY

To investigate the effect of Quadrupedal Movement Training on Flexibility and Hitting Accuracy on Amateur Lawn tennis players

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OBJECTIVES OF THE STUDY

First objective :

To investigate the effect of Quadrupedal Movement Training on Flexibility using Shoulder Reach Flexibility test for shoulder and Sit & Reach test for lower back and lower limb.

Second objective :

To investigate the effect of Quadrupedal Movement Training Hitting Accuracy using Hitting Accuracy Tennis Test

HYPOTHESIS OF THE STUDY

Null Hypothesis:

H0 1: There will be no significant impact of Quadrupedal Movement Training on flexibility in Amateur tennis players

H0 2: There will be no significant impact of Quadrupedal Movement Training on hitting accuracy in Amateur tennis players.

Alternate Hypothesis:

H1: There will be significant impact of Quadrupedal Movement Training on flexibility in amateur tennis athletes

H2: There will be significant impact of Quadrupedal Movement Training on hitting accuracy in amateur tennis athletes

REVIEW OF LITERATURE

1. Exercise Training and Physical Fitness in Young Tennis Players: A Systemic review (2022): The systematic literature reviewed by Xiao aims to investigate the effects of exercise training on various components of physical fitness, specifically focusing on young tennis players. This review concludes that exercise training interventions have a positive effect on the physical fitness of young tennis players, particularly in enhancing speed and agility and there is insufficient evidence to support its effectiveness on flexibility, endurance of young tennis players.

2. Anthropometric Characterization and Physical Performance by Age and Biological Maturation in Young Tennis Players (2021): This study by Pablo Luna-Villouta et al assess various physical performance attributes, including flexibility, strength and agility in young athletes, particularly focusing on differences between genders and they highlighted the importance of flexibility and agility drills for athletic performance, observing that females performed better than males in both sit-and-reach and shoulder flexibility tests. These findings suggest that targeted flexibility protocols could significantly improve performance, particularly for male athletes. Further research is needed to fully understand the impact of flexibility development and to optimize training programs for young athletes of all genders.

3. Flexibility of internal and external glenohumeral rotation of junior female tennis players and its correlation with performance ranking (2016) : Ching-Cheng Chian evaluated shoulder rotation flexibility in junior female tennis players, focusing

on bilateral differences and its correlation with performance ranking. Adequate Glenohumeral rotation for optimal performance in junior female tennis players. It identified a significant difference in internal rotation between the dominant and non-dominant shoulders, which may negatively impact performance rankings. The authors recommended that coaches and physiotherapists include targeted shoulder flexibility exercises in training and conduct regular assessments to detect deficiencies early, thereby enhancing performance and reducing injury risk among young tennis players.

4. Analysis of Ball Speed and Accuracy of Groundstrokes on a Clay Court in Young Tennis Players (2024): Teeraphan Sangkaew et al, analysed running groundstroke accuracy and speed in young male tennis players on clay, examining their impact on overall performance. This study highlights the importance of hitting accuracy in youth tennis. Results showed significantly greater accuracy and speed with the forehand compared to the backhand. Coaches should prioritize both accuracy and speed in groundstroke training to enhance young athletes' overall game and competitive readiness

5. The value of technical characteristics for future performance in youth tennis players (2021): Barbara C. H. Huijgen, Chris Vissche et.al whether technical characteristics, specifically ball speed and accuracy, predict both current (under-14) and future (under-18) tennis performance in youth players. Accuracy and shot speed are key predictors of current and future performance in young male tennis players. Future elite

players showed greater accuracy, especially in dynamic game situations. Effective upper-lower limb coordination alongside specific drills, improves stroke accuracy by optimizing power and control, enabling responsiveness to unpredictable play. This emphasizes accuracy as a fundamental aspect influencing match outcomes.

6. The Effects of a Novel Quadrupedal Movement Training Program on Functional Movement, Range of Motion, Muscular Strength, and Endurance (2022): Jeffrey D. Buxton, Philp J. Prins assess the impact of a Novel Quadrupedal movement training (QMT) program on various fitness components, specifically focusing on functional movement, dynamic balance, range of motion, and upper body strength and endurance. Based on this study Novel Quadrupedal movement training would be used as alternative strategy in training program for enhancing overall fitness. By emphasizing dynamic, multi-joint movements, Novel Quadrupedal movement training promotes whole-body stabilization, coordination, functional movement and range of motion and significant muscular endurance but did not much show improvement in upper body strength among physically active individuals.

7. Quadrupedal Movement Training Improves Markers of Cognition and Joint Repositioning (2016): Mohamed Yusuf, Martyn Mattews examined Quadrupedal Movement Training as an effective intervention for enhancing cognitive markers and joint function. This study shows that as Quadrupedal movement training is progressive

and challenging task requires coordination of all 4 limbs with trunk control, has beneficial impact on cognitive flexibility and joint repositioning or proprioception.

8. Test-retest reliability for hitting accuracy tennis test (2011): Stecker, E. Foster, E. B. & Pascoe aimed to test-retest reliability of Hitting Accuracy Tennis Test (HATT) is to assesses its consistency in measuring ground stroke accuracy across multiple trials, analysing performance in various directions. The study found the Hitting Accuracy Tennis Test a reliable and straightforward tool for measuring tennis accuracy (total score, unforced errors, and shot index), demonstrating consistent results across trials, making it useful for coaches and players to monitor and improve performance.

9. Reliability and validity of tests for assessing physical fitness in gymnasts (2022): Salse-Batán a, Silvia Varela aimed at analysing the reliability and validity of tests for assessing physical fitness in gymnasts. They concluded that reliability of non-specific shoulder flexibility was the most reliable (ICC = 0.996) and sit and reach test (ICC = 0.998).

10. Impact of fitness characteristics on tennis performance in elite junior tennis player (2016): Ulbricht, A, Fernandez-Fernandez, aimed at to test whether physical characteristics are related to players' competitive level (i.e., national youth ranking) and secondary aim was to compare adolescent tennis players by performance level (i.e., regional selected players and the national team). They concluded that the importance

of certain physical attributes, especially serve velocity and strength- and power-related variables (upper body), and suggest the need to include these parameters in the area of training, physical testing, and talent identification of young tennis players.

11. The Core Mobility Series: A Dynamic Warm-up Tool (2015): Mitch Hauschildt, Brett McQueen ,Geoffrey Stanford assess the Core Mobility Series (CMS) as a structured, equipment-free dynamic warm-up designed to enhance joint mobility, stability, and motor control. The findings highlight that CMS is a comprehensive and versatile sequence of whole-body movements that mimics sport-specific skills, thereby improving performance and reducing injury risk. With its adaptability across different athletic levels, the CMS serves as both a performance enhancement and injury-prevention strategy, making it a valuable addition to training programs.

12. Comparison of muscle activation during quadrupedal movement training and traditional bodyweight exercises (2024): Jeff Buxton, Margaret Daugherty, Rachel Grubbs aimed to compare muscle activation during quadrupedal movement training (QMT) and traditional bodyweight exercises to determine their effectiveness in engaging trunk and limb muscles. The results demonstrated that QMT elicited higher activation in several muscle groups, particularly the lower back and hamstrings, when compared to squats and planks. This suggests that QMT not only improves overall muscle activation but also provides a superior stimulus for posterior chain engagement, making it a valuable alternative for performance enhancement and rehabilitation programs.

13. Epidemiology of Tennis-Related Injuries Among Competitive Youth Players in Tunisia: Frequency, Characteristics, and Management Patterns (2025):

Saoussen Layouni, Ismail Dergaa aimed to determine the frequency, characteristics, and management of tennis-related injuries among competitive Tunisian youth players and concluded that Lower limbs were most affected (58.5%), followed by upper limbs (32.8%) and high frequency of recurrent injuries and limited rehabilitation highlight critical gaps in injury management, emphasizing the need for targeted neuromuscular training, accessible rehabilitation, and standardized return-to-play protocols

14**. Effects of functional training on tennis-specific physical fitness and functional movement screen in junior tennis players** WenshengXiao , Xiaorong Bai, KimGeokSoh aimed to compare the effects of 12-week functional training versus traditional resistance training on tennis-specific physical fitness and functional movement in junior tennis players and concluded that while both training types improved physical fitness measures, only traditional training showed limited or no significant changes in flexibility, as indicated by the sit-and-reach test. This highlights that incorporating functional training can better support the development of functional movement and flexibility, which are crucial for injury prevention and overall athletic performance in junior tennis players and different types of functional training should be a part of their practice.

15. Sequencing effects of neuromuscular training on physical fitness in youth elite tennis players (2023): Fernandez-Fernandez, J, Granacher, U aimed to investigate the effects of the within-session sequencing of neuromuscular developmental sequence relative to tennis-specific practice on physical fitness components in prepubertal tennis players and concluded that neuromuscular development enhances performance by improving muscular strength, power, coordination, and neuromuscular efficiency,

which are crucial for executing technically accurate and powerful shots. Implementing NMDS prior to tennis practice maximizes these benefits, leading to better shot accuracy and overall tennis performance in youth players.

16. Quadrupedal Movement Training A Brief Review and Practical Guide (2023): Adam C. Eckart aimed to review how quadrupedal movement training can enhance motor skills, stability, and function across different populations and concluded that quadrupedal movement training offers a promising avenue for developing functional movement skills that are closely aligned with natural motor patterns. These practices not only improve physical capacities such as stability, mobility, and coordination but also have positive implications for cognitive function and lifelong physical activity.

17. Youth tennis player serves accuracy with respect to different rackets variations (2020): Acuratețea serviciului aimed to evaluate the impact of different tennis racket variations on the serving accuracy of young players, highlighting the importance of accuracy in youth tennis development and highlight the importance of developing versatile movement patterns through targeted practice, noting that more diverse and repeated movements are essential during early training periods to improve serve accuracy and overall motor skills in youth tennis players. This underscores that fostering movement variability and practicing under varied conditions are critical strategies for advancing performance in young athletes.

18. Training Tennis through Induced Variability and Specific Practice: Effects on Performance in the Forehand Approach Shot (2024): Vinicius Oliveira, Ruperto Menayo aimed to study was to investigate whether applying induced variability during training could enhance the accuracy of the forehand approach shot in tennis and underscores the importance of incorporating varied training methods, such as induced variability, to improve forehand shot accuracy. Results suggest that training under variable conditions enhances skill retention more effectively than traditional methods. Therefore, employing diverse and adaptable approaches is crucial for optimizing technical performance in tennis**.**

19. Acute and Time-Course Effects of Traditional and Dynamic Warm-Up Routines in Young Elite Junior Tennis Players (2016) Francisco Ayala1☯, Víctor Moreno-Pérez aimed to analyze and compare the acute effects of two different WU modalities (traditional WU[TWU]and dynamic WU[DWU] on physical performance(i.e., CMJ, sprint, serve speed and accuracy) in elite junior players and concluded that for optimal performance in these elite ten nis players, DWU routines should be performed prior to formal training and competition rather than TWU routines.

20. Association Between Spikes in External Training Load and Shoulder Injuries in Competitive Adolescent Tennis Players: The SMASH Cohort Study (2022) Fredrik Johansson, Ann Cools, Tim Gabbett examined whether workload spikes and shoulder flexibility deficits affect shoulder injuries and shooting accuracy in young tennis players and concluded that workload spikes are linked to shoulder injuries and reduced flexibility, which can impair shooting accuracy. Consistent training and

improved shoulder mobility is key to injury prevention and performance

METHODOLOGY & PROCEDURE

- **STUDY DESIGN:** Randomized Controlled Trial
- **STUDY POPULATION:** Amateur Tennis Player
- **SAMPLE SIZE:** 30
- **SAMPLING TECHNIQUE:** Convenient sampling
- **STUDY SETTING:** ACE BASE Tennis Academy, Bhubaneswar
- **STUDY DURATION:** 1 year
    - Ethical clearance: 4 months
    - Sample selection, data collection: 4 months
    - Statistical analysis, results analysis, discussion: 4 months
- **MATERIALS USED:**

Recording sheets, Ruler, Box, 2 Smart Phone, Tennis Ball, Chalk, Cones, Tennis Racquet

- **INCLUSION CRITERIA:**

  - Amateur lawn tennis player
  - Age between 14-18 years both male and female
  - Athletic Identity Measurement Scale
  - According to ITF & USTA should play 7-8 hours Per week

- **EXCLUSION CRITERIA:**

  - Any recent fracture in the upper limb or lower in the past 6 months.
  - Unresolved underlying condition or any recent injury since 6 months.
  - Subjects who were not prepared to join the research

- **OUTCOME MEASURES**

1. HITTING ACCURACY TENNIS TEST

A tennis court was divided into 12 boxes (2.06m wide by 2.74m long), covering about 75% of singles court. Using Vergauwen's definitions, shots were classified as :

- Neutral (landing near the court's center, positions 2 & 4)
- Defensive (landing inside the service line, positions 1 & 3)
- Offensive (landing near the sidelines, positions 5 & 6).

This system enabled analysis of accuracy, shot placement, total errors, and the location of those errors, providing more detailed information than traditional methods

Testing procedure

1. Players performed a 15-minute dynamic warm up session which is further followed by 5 minutes of rally session.

2. Each player executed 15 continuous strokes i.e. forehand and backhand which are directed towards court line.

3. Sequence of shot directions was varied randomly for every player to minimize bias.

4. Recovery break of about 45-60 seconds was allowed before switching to a new stroke direction

Methods to score

1. Scores were given according to landing position of ball in the different zones.
2. Stoke that failed to reach the zone were classified as an unforced error.

3. Shot index means deducting count of unforced errors that landed in the prime scoring zones.

2. SHOULDER FLEXIBILITY TEST:

Steps for test-

1. Raise your right arm vertically overhead.

2. Flex right elbow to hand drops behind the head.

3. Keeping upper arm steady, palm places in middle of scapula

4. Left arm extended backward to the torso with palm facing outward

5. Attempt to make contact between the fingers of both hands.

6. Perform same sequence on other side.

Scoring –

1. Good – Fingertips make contact

2. Fair – Fingers remain apart but within 5 cm distance

3. Poor – Separation exceeds 5 cm

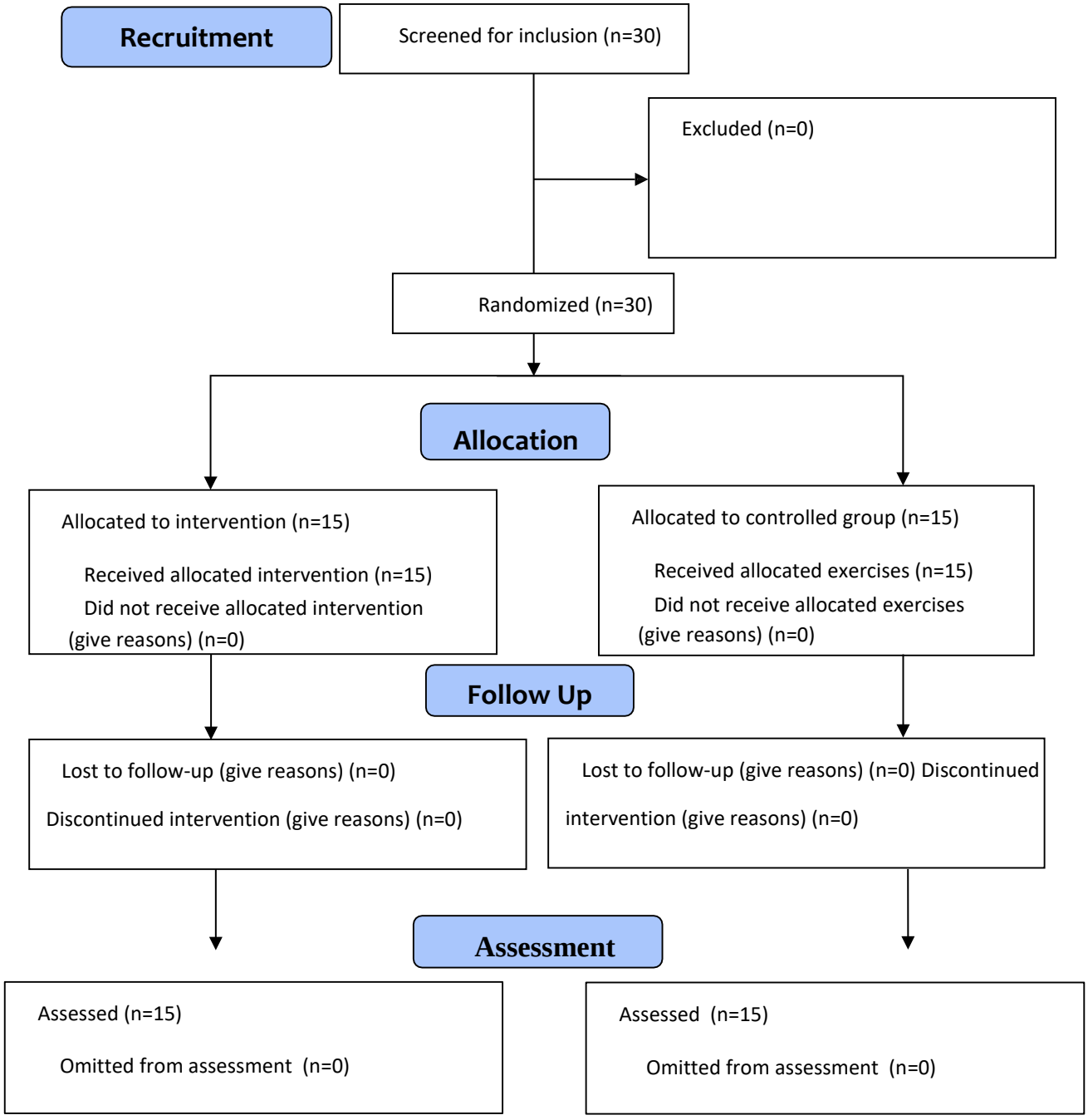
3. SIT AND REACH TEST

Steps for test :

1. Participant sits with their legs straight out in front of them.
2. Upper body were perpendicular to the legs, with hands placed one over the other
3. Participant leans forward to maximum reach and maintains position for at least 5 seconds
4. Measurement were noted and repeated for three trials were taken.
5. Highest value was taken as final score.

PROCEDURE

FIGURE 1: CONSORT 2010 Participant flow scheme



1. Ethical clearance was obtained from the Institutional Ethics Committee (IEC) to ensure all protocols comply with ethical standards. Following this, the screening of subjects was carried out in two phases

2. The experiment was done at Ace Base Tennis Academy, Bhubaneswar, Odisha 30 subjects were recruited according to the inclusion and exclusion criteria.

3. General demographic information of all the subjects was collected.

4. Permission from the academy administration, informed written consent from all the subjects, and the experiment procedure and potential benefits and safety precautions against risks were explained.

5. The study was conducted for 4 weeks and had 12 experimental sessions.

6. Thirty eligible participants were divided into control and intervention groups.

7. The intervention group received Quadrupedal Movement Training, whereas the control group performed independent footwork drills, strengthening, and stretching.

8. All the participants had their performance outcomes of hitting accuracy and flexibility measured in the form of performance of hitting accuracy and flexibility through the Hitting Accuracy Tennis Test (HATT), Shoulder Flexibility Test, and Sit-and-Reach Test.

9. These data were recorded both before the study was started and following the 4-week intervention.

10. No adverse effects were noted throughout all the training sessions

TABLE 1: Illustrates the group wise assignment and the corresponding interventions

INTERVENTION GROUP	CONVENTIONAL GROUP
QUADRUPEDAL MOVEMENT TRAINING (n=15)	**SELF ADMINISTERED STRETCHES AND SELF-ADMINISTERED STRENGTHENING AND FOOT DRILLS EXERCISES (n=15)**
PARTICIPANTS OF THIS SECTION ENGAGED IN QUADRUPEDAL MOVEMENT TRAINING	**PARTICIPANTS OF THIS SECTION ENGAGED INDIVIDUALLY PERFORMED STRETCHING AND STRENGTHENING AND FOOT DRILL EXERCISES**
BASE LINE MEASUREMENT **WARM-UP – 15 MINUTES** **TRAINING PROTOCOL – 40 MIN/SESSION** **CONDUCTED THRICE WEEKLY OVER FOUR WEEKS**	**BASE LINE MEASUREMENT** **WARM-UP – 15 MINUTES** **TRAINING PROTOCOL – 40 MIN/SESSION** **CONDUCTED THRICE WEEKLY OVER FOUR WEEKS**

Week 1 & 2 **• Wrist Rolls – Slow circular rotation of the wrists.** **• Wrist Waves – Wavelike movements of the wrists in an upward and downward motion.** **• Prayer Stretch – Pressing palms together, slowly lowering them.** **• Quadruped Wrist Activation – On hands and knees, slightly shifting weight.** **• Form Stretch – Turning palms at various angles while stretching.** **• Travelling Forms – Forward crawl, backward crawl, side step crawl, diagonal crawl.** **• Switches – Inward switch, outward switch, palm flip, fingertip switch.** **Week 3 & 4**	**Footwork – side steps, cross steps, side shuffles, ladder runs** **Service – forward, backhand, forehand long service, back hand short service** **W-drill, cone drills, cone hop, the wheel, x-drill** **Individually performed stretching** **Individually performed strengthening.** **FINAL MEASUREMENT**

• Form Stretch Flows – Wrist mobilizations involving gentle circle shifting of wrists on the floor. **• Switches – Inward switch, outward switch, palm flip, fingertip switch.** **• Flows – Wrist wave flow, prayer-to-stretch flow, crawl-to-switch flow.** **POST-INTERVENTION SCORING**	
BOTH BASELINE AND FINAL MEASUREMENT WERE CONDUCTED THROUGH : .HITTING ACCURACY TENNIS TEST (HATT) .SHOULDER FLEXIBILITY TEST SIT AND REACH TEST	**BOTH BASELINE AND FINAL MEASUREMENT WERE CONDUCTED THROUGH** HITTING ACCURACY TENNIS TEST (HATT) SHOULDER FLEXIBILITY TEST SIT AND REACH TEST

STATISTICAL ANALYSIS

Data was analysed using SPSS 22.0 (SPSS Inc., Chicago, IL), and the level of significance was set at $p<0.05$.

Finding normality: Normality was taken out using the Shapiro-Wilk test

Descriptive statistics: The data were presented using mean and standard deviation.

Inferential statistics: Paired t-test/dependent t-test was used to find out the statistical difference within groups (pre- and post-intervention). An unpaired t-test/independent t-test was used to measure between groups (EG &CG) difference of the variables.

RESULTS

30 amateur tennis players fitting the inclusion criteria and consenting to participate were recruited and were randomised using the chit method. Allocation of 30 players with 15 players in control group and

15 intervention group. After baseline assessment, control group continued with the routine practice and intervention group received the allocated intervention along with the routine practice. Data analysis was done using SPSS. Descriptive statistics were analysed for each treatment group. Data was then tested for Normality using the Shapiro-Wilk test. Students t test and Wilcoxon sign rank test for intragroup & independent t test and Mann Whitney U test was used for intergroup comparison. For all analyses, statistical tests were one-tailed, set at 95% confidence interval

and the threshold of the p value considered as significant was set at <0.05 or <0.001

Outcome Measure	Within group	Between Group
Right Sit and reach test	Student t test	Independent t test
Left Sit and reach test	Wilcoxon sign rank	Mann Whitney U test
FHAT FHCC	Student t test	Independent t test
FHULT	Student t test	Independent t test
Right shoulder flexibility test	Student t test	Independent t test

Left shoulder flexibility test	Student t test	Independent t test

Table 2: List of statistical tests applied for each outcome measure

BASELINE ANALYSIS

	Interventional	Control
Age	15.87 ±1.55	15.53 ± SD 1.41

The bar graph displays average age across both sets, showing comparable mean values between intervention and control participants

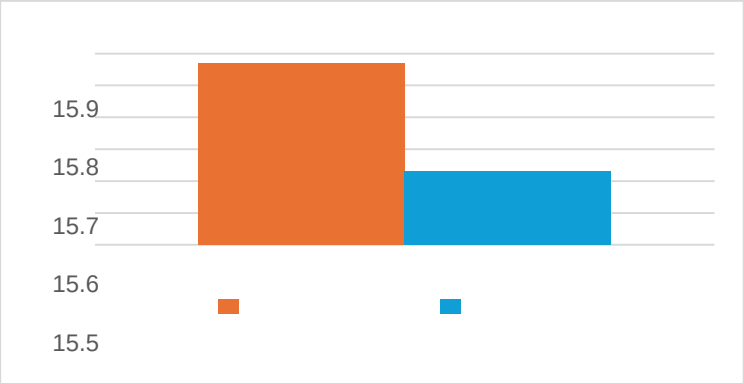


Figure 1 mean age of participants in both groups

The pie chart depicts sex-wise division within the interventional group, ensuring gender representation

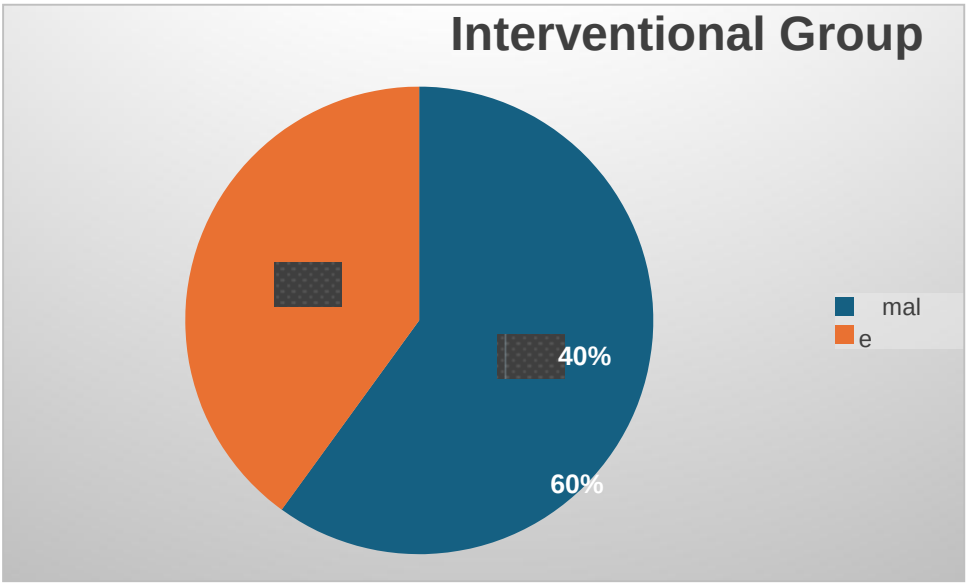


Figure 2 gender distribution intervention group

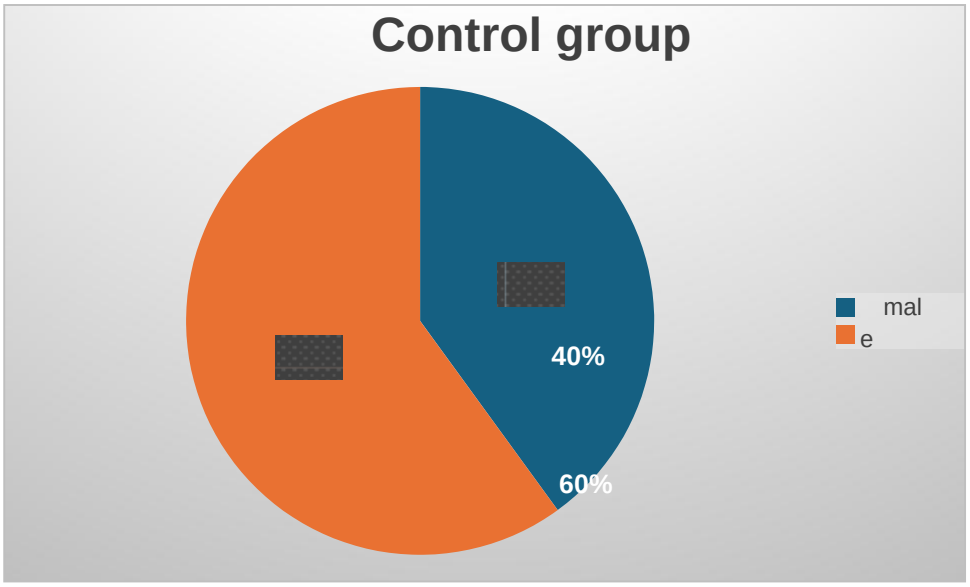


Figure 3 gender distribution control group

The pie chart demonstrates gender distribution in the control arm, confirming both genders were included.

NORMALITY

The Shapiro-Wilk test followed near-normal patter, confirming the choice of statistical methods. Normality assessment indicated that mostly outcome variables met the assumptions required for further analysis.

SIT AND REACH TEST

1. Right Sit and Reach Test

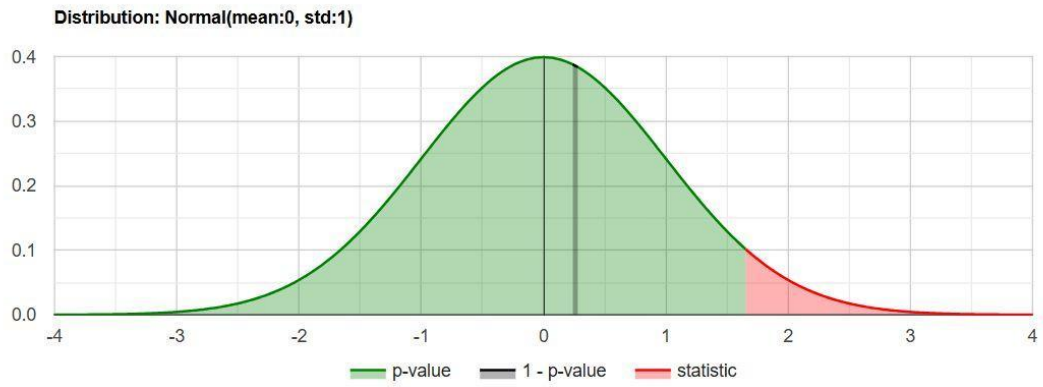


Figure 4 bell curve for right sit and reach

Curve shows data points which indicates that right sit and reach data was normally distributed

Left sit and reach test

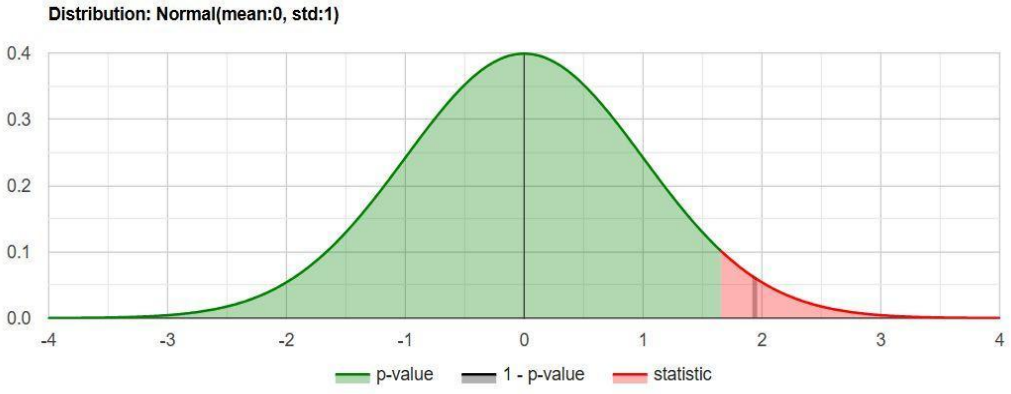


Figure 5: Bell curve for Left sit and reach

Curve shows data points which indicates that left sit and reach data was normally distributed

FHATT FHCC

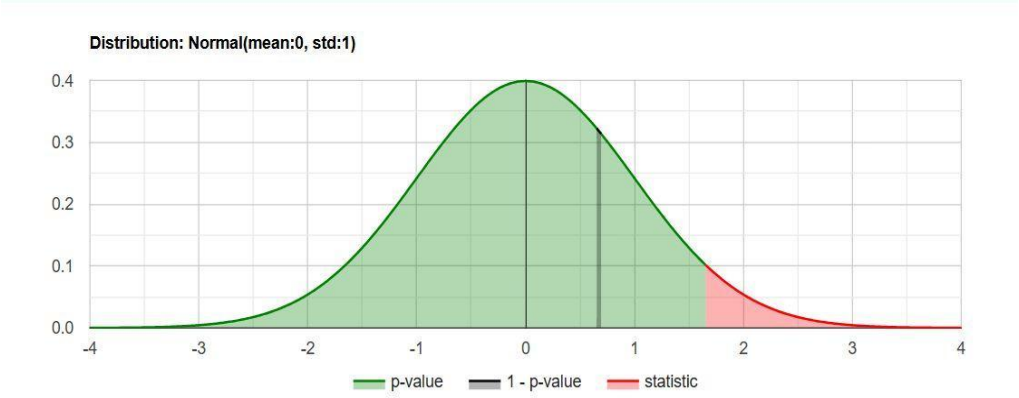


Figure 6: Bell Curve for FHAT FHCC

The FHAT FHCC approximates Gaussian distribution which adheres to normality assumptions.

Fhult

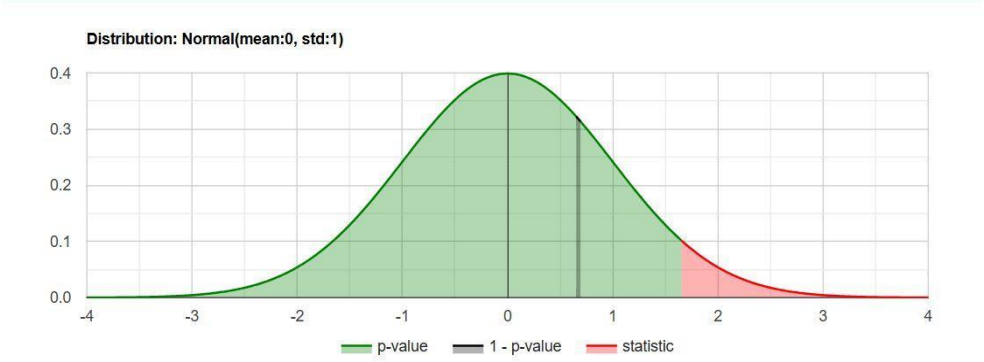


Figure 7: Bell curve for FHULT

Curve reflects a standard bell-shaped distribution and data symmetry.

Right shoulder flexibility

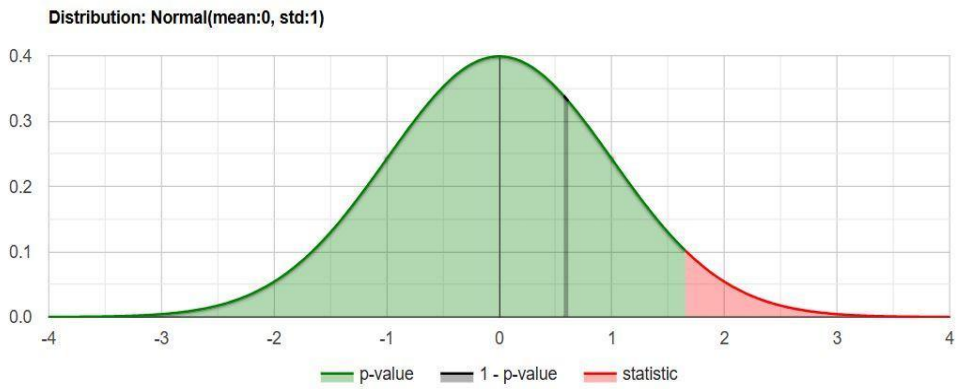


Figure 7: Bell curve for Right shoulder flexibility

Curve resembles a normal curve and data symmetry

Left shoulder flexibility

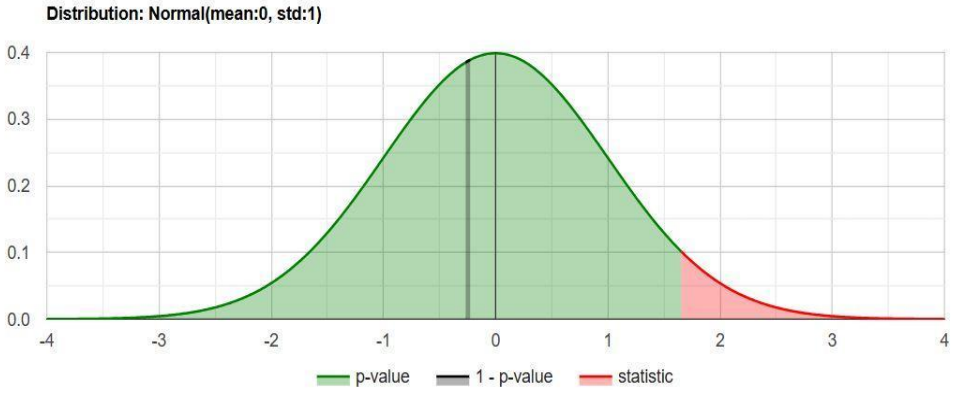


Figure 8: Bell curve for left shoulder flexibility

Curve resembles Gaussian distribution validating parametric methods

INTRAGROUP ANALYSIS

Right Sit and reach test

Table 3: Intragroup comparisons with mean, p-value and effect size for right sit and reach test

Groups	Pre mean	Post mean	Mean difference	Pvalue	Effect size
Interventional group	3.22 ± 0.95	4.88 ± 1.44	-1.66	<.001	0.84
Control group	3.68 ± 1.58	3.82 ± 1.38	-0.1400	0.484	0.18

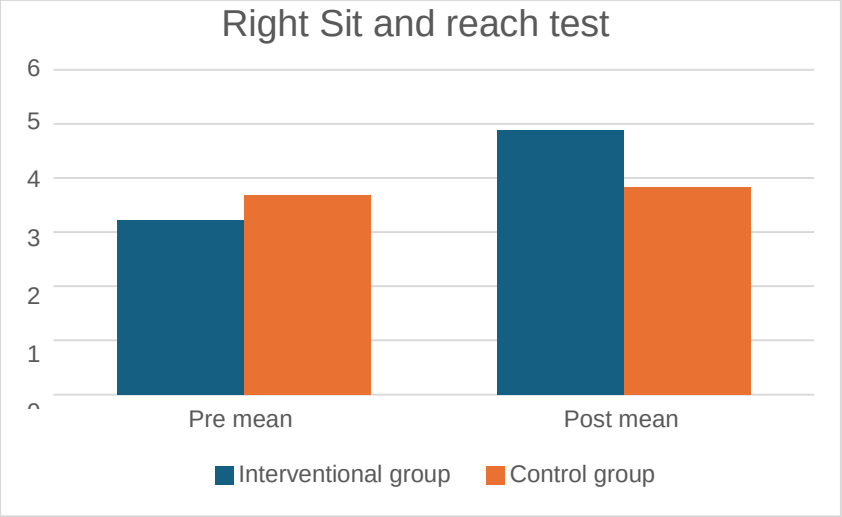


Figure 9: Within group changes for right sit and rea

Left sit and reach test

Groups	Pre mean	Post mean	Mean difference	Pvalue	Effect size
Interventional group	2.61 ± 0.59	4.53 0.87	-1.92	<.001	0.87
Control Group	3.93 ± 1.58	4.01 ± 1.3	-0.200	0.66	0.143

Table 4: Intragroup comparisons with mean, p-value and effect size for left sit and reach test

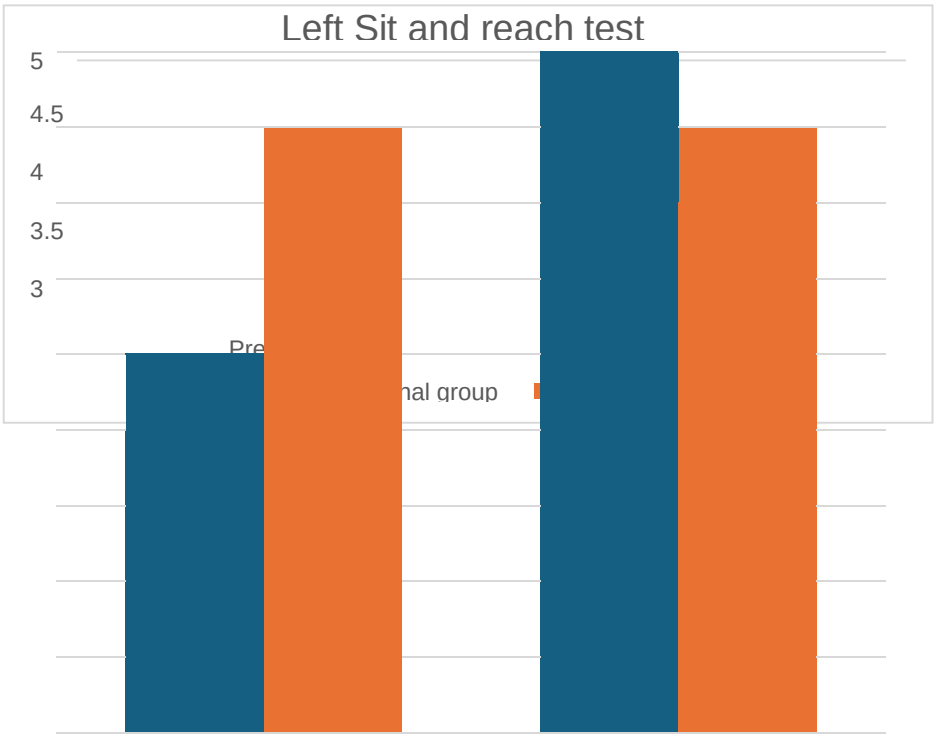


Figure 10: Within group changes for left sit and reach test

FHAT FHCC

Groups	Pre mean	Post mean	Mean difference	Pvalue	Effect size
Interventional Group	8.33 ± 0.98	10.53 ± 1.13	-2.20	<.001	0.88
Control Group	8.13 ± 1.13	8.73 ± 1.44	-0.6	0.094	0.5

Table 4: Intragroup comparisons with mean, p-value and effect size for FHAT FHCC

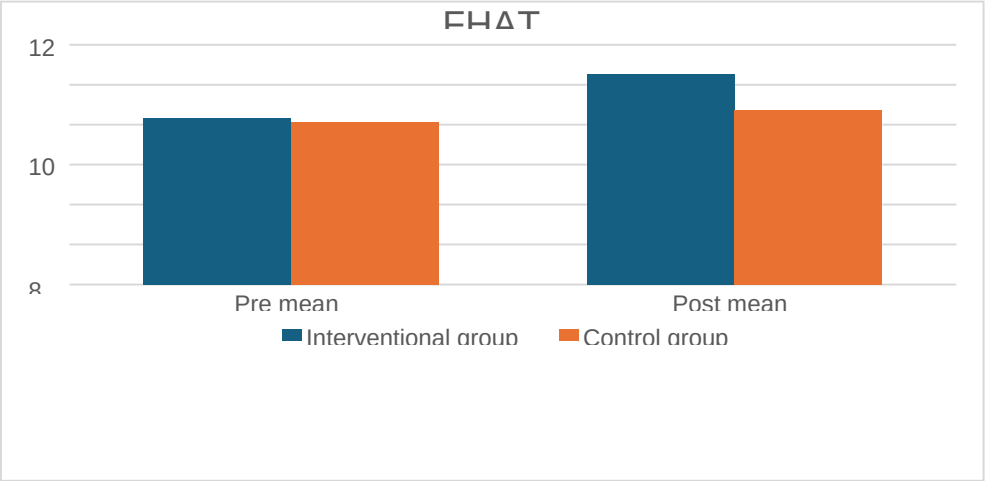


Figure 11: Within group changes for FHAT FHCC

FHULT

Groups	Pre mean	Post mean	Mean difference	Pvalue	Effect size
Interventional Group	8.4 ± 0.99	11 ± 1.36	-2.60	<.001	0.88
Control Group	8.47 ± 0.99	9.6 ± 0.63	-1.1333	<.001	1.525

Table 4: Intragroup comparisons with mean, p-value and effect size for FHULT

Table 4: Intragroup comparisons with mean, p-value and effect size for FHAT FHCC

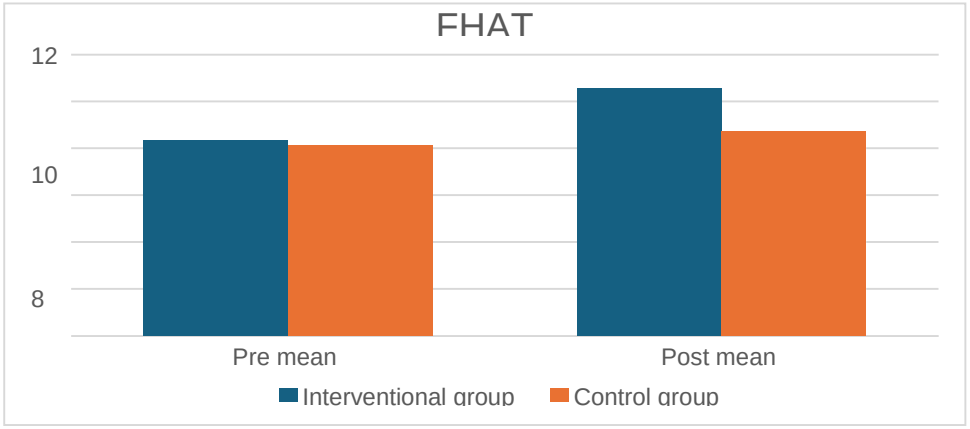


Figure 11: Within group changes for FHAT FHCC

FHULT

Groups	Pre mean	Post mean	Mean difference	Pvalue	Effect size
Interventional Group	8.4 ± 0.99	11 ± 1.36	-2.60	<.001	0.88
Control Group	8.47 ± 0.99	9.6 ± 0.63	-1.1333	<.001	1.525

Table 4: Intragroup comparisons with mean, p-value and effect size for FHUL

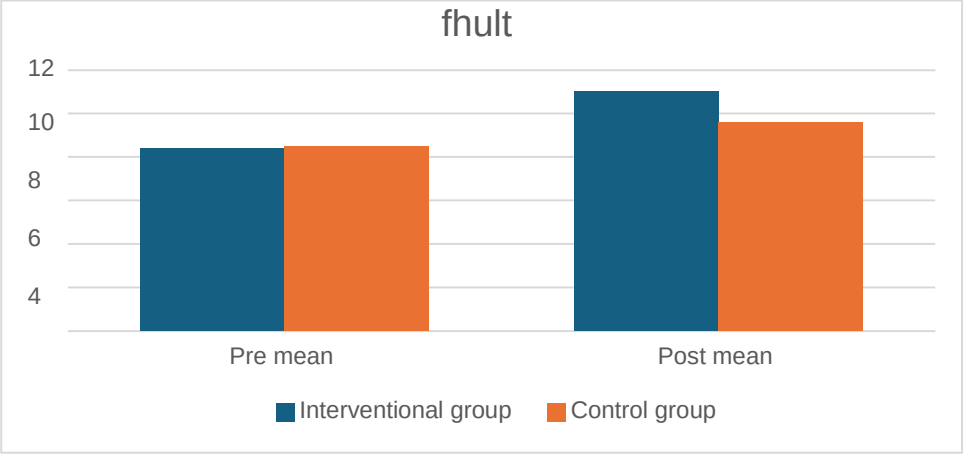
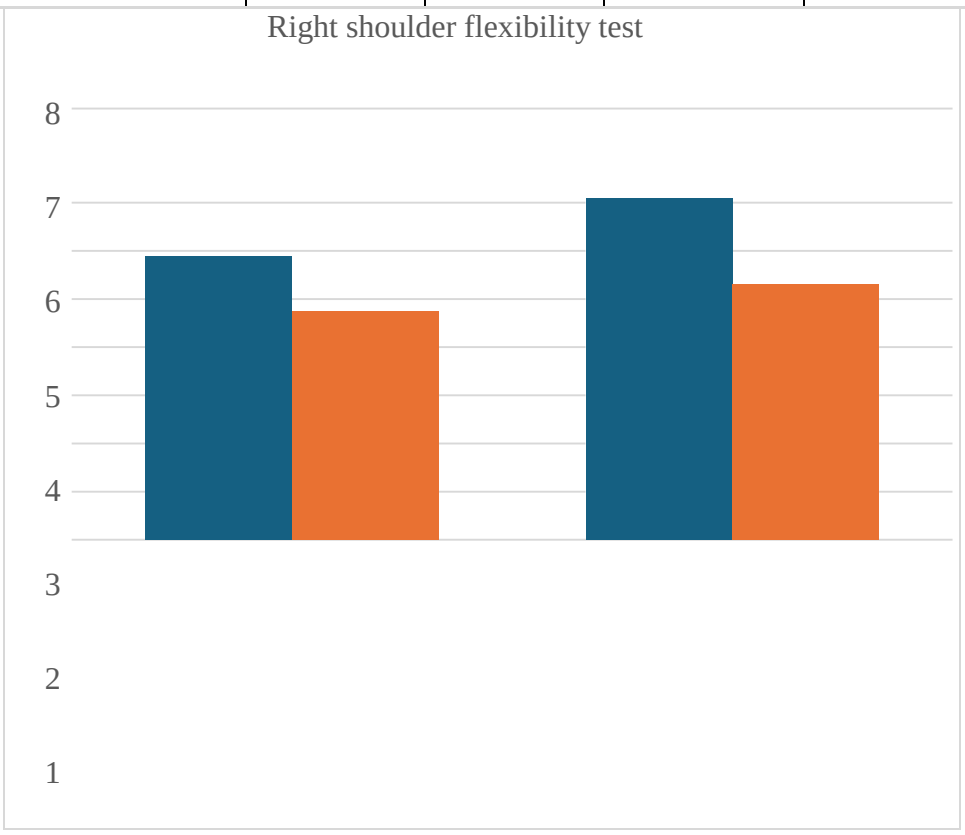


Figure 12: Within group changes for FHULT

Right shoulder flexibility test

Table 4: Intragroup comparisons with mean, p-value and effect size for Right Shoulder Flexibility Test

Groups	Pre mean	Post mean	Mean difference	Pvalue	Effect size
Interventional Group	5.9 ± 1.16	7.1 ± 1.08	-1.20	<.001	1.49
Control group	4.75 ± 1.46	5.31 ± 1.55	-0.5533	<.001	1.3



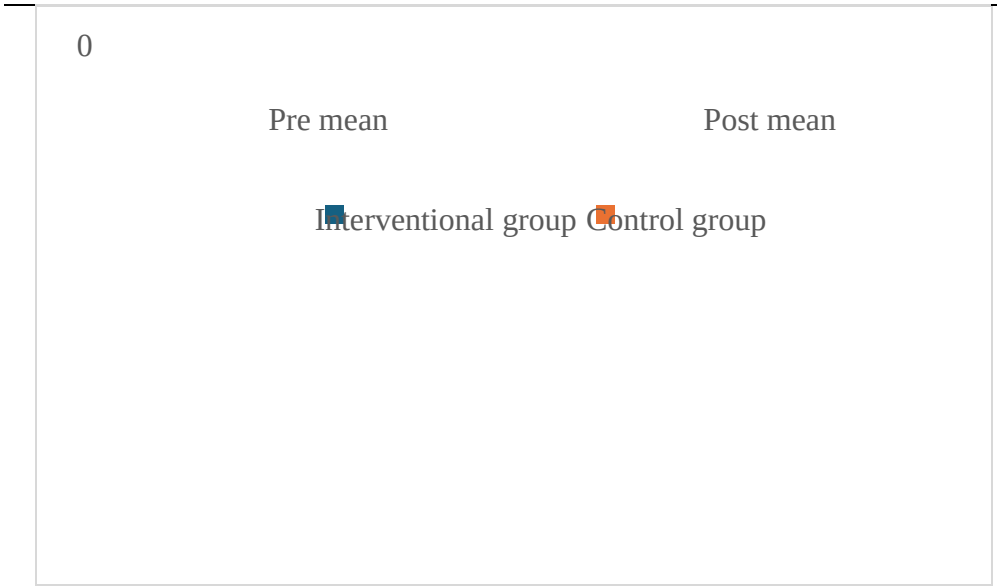


Figure 12: Within group changes for Right shoulder flexibility test

For both groups, there is a significant difference in pre- and post- values for the right shoulder flexibility test

Left Shoulder Flexibility Test

Groups	Pre mean	Post mean	Mean difference	Pvalue	Effect size
Interventional Group	4.85 ± 0.91	6.54 ± 0.92	-1.69	<.001	2.37
Control Group	4.57 ± 1.45	5.1 ± 1.56	-0.5267	<.001	1.110

Table 5: Intragroup comparisons with mean, p-value and effect size for Right Shoulder Flexibility Test

For both the groups, there is a significant difference in pre- and post- values for the left shoulder flexibility test with large impact factors for group respectively

Figure 12: Within group changes for Right shoulder flexibility test

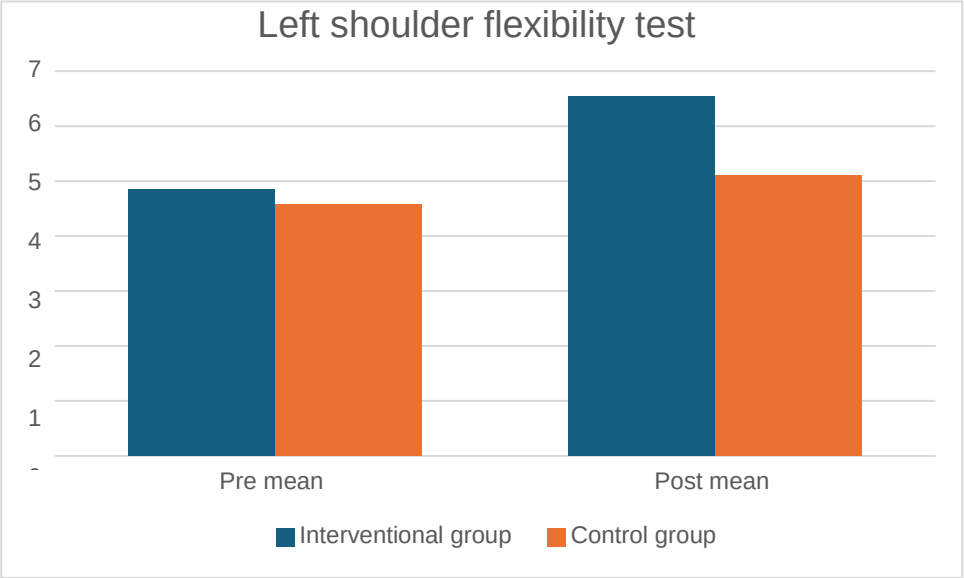


Figure 12: Within group changes for Left shoulder flexibility test

INTERGROUP ANALYSIS

	INTERVENTIONA L GROUP	Control group	Pvalue	Effec t size
Right sit and reach test	1.66 ± 0.49	0.14 ± 0.2	0.117	0.5
Left si t and reach Test	1.9 ± 0.28	0.2 ± 0.28	0.0504	0.099

Fhalt	2.2 ± 0.15	0.6 ± 0.13	<0.001HS	0.58
Fhult	2.6 ± 0.37	1.3 ± 0.36	<0.001HS	0.55
Right shoulder flexibility test	1.20 ± 0.8	0.5533 ± 0.09	<0.001HS	0.63
Left shoulder flexibility Test	1.69 ± 0.01	0.5267 ± 0.11	<0.001HS	0.46

Table 6: Intergroup comparisons with mean, p-value and effect size for

For the right sit and reach test, the interventional group had a higher mean score (1.66 ± 0.49) than the control group (0.14 ± 0.20), no meaningful statistical difference was detected (p = 0.117) despite a medium magnitude of effect (d = 0.50).

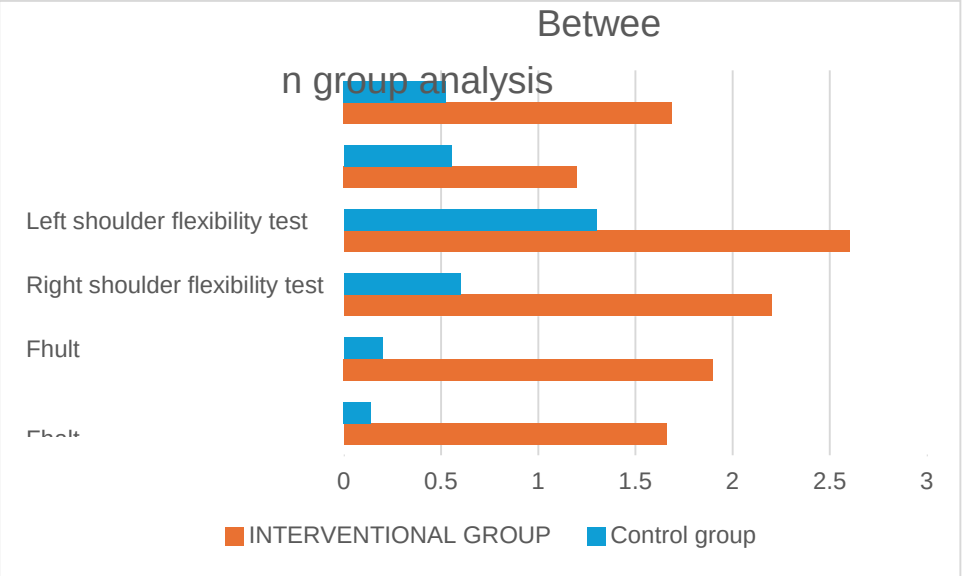
In contrast, the left sit and reach test approached statistical significance (p =

0.0504) with mean scores of 1.90 ± 0.28 in the interventional group and 0.20 ± 0.28 in the control group; however, the effect size was small (d = 0.099), indicating limited practical impact.

For F, a significant improvement was observed in the interventional group (2.2 ± 0.15 and 1.3 ± 0.36) compared to the control group (0.6
± 0.13), with highly significant p-values (<0.001) and moderate effect sizes (d = 0.58 and d = 0.55, respectively), reflecting a meaningful clinical difference.

In terms of shoulder flexibility, the right side showed significantly better scores in the interventional group (1.20 ± 0.80) compared to the control group (0.5533 ± 0.09) ($p < 0.001$, d = 0.63) showing effectiveness of interventional group due to higher mean value indicating a moderate-to-large effect. Similarly, the left shoulder

flexibility also showed a significant difference ($p < 0.001$), with scores of 1.69 ± 0.01 in the interventional group and 0.5267 ± 0.11 in the control, though the effect size was smaller ($d = 0.46$).



DISCUSSION

Within-group analysis of the intervention cohort revealed that a variety of domains of flexibility in the intervention group were statistically and clinically significant. Specifically, significant improvement ($p<0.001$) was recorded in the F-measures of the tests, the right and range of motion of the left shoulder tests, and the bilateral sit-and-reach tests. These improvements were accompanied by moderate to large effect sizes(>0.5) that was significant and demonstrated considerable practical relevance. These findings suggest that musculoskeletal flexibility and joint mobility of junior amateur tennis players were considerably enhanced by the quadrupedal movement training (QMT) program.

In the control group, participants continued their standard training regimen, which included whole body cardiorespiratory fitness conditioning, free loading resistance or apparatus-based strength training, and sustained stretch. Within this group, significant improvements were noted only in right and left shoulder flexibility, likely attributable to the stretching and upper body engagement embedded in their routine training. However, other measured domains did not show statistically significant ($p>0.05$) suggesting that general training alone was insufficient to elicit broader flexibility improvements within the study timeframe.

The QMT program's efficacy was further demonstrated by between- group analysis. Comparing the intervention and control groups revealed significant differences in bilateral shoulder flexibility as well as both F-measures. These results are explained by the targeted nature of the QMT exercises, which used multifaceted, structured movements to specifically target joint mobility and flexibility. This distinction demonstrates how QMT is more beneficial than

traditional training in fostering the functional mobility improvements necessary for tennis performance.

These results are particularly important in the context of tennis, in which the imbalances of flexibility include preponderant. Past literature has verified clearly that internal rotational range of the shoulder joints is more often less in Within the primary shoulder than in such non-dominant side in junior female tennis players. A decrease in internal rotation is likely to harm stroke, performance, and risk of injury. Therefore, the prevention role, as well as the performance-enhancing role, can be used by the shoulder mobility improvement due to QMT.

Moreover, anthropometric research involving tennis players has proved the significance of integrating flexibility-based interventions with endurance training to adapt to the physical demands of competitive tennis.

Quadrupedal movement training is a body based no-equipment modality of movement that provides the benefit of this mode of exercise; it is practical in terms of implementation, such as rehabilitation centres. The fact that it has enjoyed increasing popularity in the field of fitness, strength training and sports rehabilitation indicates its accessibility and flexibility to various levels of skills (3).

These findings support the integration of flexibility-focused interventions—not just as warm-up or cool-down routines—but as core components of tennis conditioning programs. The nature of the QMT intervention, which combined static stretching, traveling movement forms, switch-based transitions, flow games, and functional circuits, appears to have provided comprehensive stimuli for neuromuscular adaptation, contributing to the observed flexibility enhancements.(3)

The Hitting Accuracy Tennis Test (HATT), which measures flexibility, also demonstrated a moderately considerable enhancement in the intervention category.(4) There functioned as compelling evidence suggesting that the QMT intervention had a transferable impact on tennis-specific performance

thanks to this tool, which was created to evaluate groundstroke accuracy, directional control, and consistency across several trials. The HATT is a helpful tool for coaches and practitioners to monitor technical development and direct customized training regimens because of its dependability and simplicity of use [4] These components collectively demonstrate a player's technical proficiency, perceptual anticipation, and neuromuscular coordination. The ability to hit the ball precisely and at the right moment is crucial for preserving offensive control and reducing unforced errors in tennis, where players must quickly adjust to changing ball speeds, spins, and trajectories.[4]

Quadrupedal movement training has been shown to improve cognitive functions, also in the study of ----, which is also an important aspect in tennis player training. From a psychological standpoint, circuits, flow games, and switches enhance training engagement and lessen monotony while encouraging intrinsic motivation and a sense of play. In youth sports, where enjoyment and variety support long-term athlete development and retention, this is particularly crucial. Flow games serve as a link between physical training and the movement demands of tennis, enabling players to think and respond more fluidly during matches in addition to improving their movement efficiency

CONCLUSION

As reported by this study, Quadrupedal movement training (QMT) drastically enhances joint mobility, flexibility, as well as tennis-specialized performance in junior amateur tennis players. Intervention group was statistically significant in increased shoulder flexibility, sit-and-reach scores, and hitting accuracy, showing that QMT is a highly effective modality for inducing neuromuscular adaptation and functional mobility required for tennis performance. These results substantiate the argument that the inclusion of QMT within training programs can be effective in enhancing sporting performance and aiding in the prevention of injury, reflecting its utility and generalizability in sports conditioning

LIMITATIONS & RECOMMENDATIONS FOR FUTURE STUDY

LIMITATIONS

- . The experiment included only 30 subjects, making generalization to large populations difficult.

- The intervention was for only 4 weeks, which may be too short to evaluate sustained or long-term effects.

- Self-administered exercises from the control group may result in variation in technique and compliance, affecting outcomes.

- The research had no extended blinding protocols, which raised the likelihood of bias in assessment and reporting.

- There was minimal control of external variables like other training regimens that participants may have done in parallel, which could cause confounding outcomes

RECOMMENDATIONS FOR FUTURE STUDY

- Long-term treatment duration of 12–24 weeks might determine whether gains are maintained and define optimal training time.
- Observation of participants for 3-6 months after training would measure benefits post long term.
- Testing Quadrupedal Movement Training in people of different ages, from different cultures, and with different levels of baseline fitness would determine how transferable these findings might be.
- Whether or not benefits to sports other than tennis exist for Quadrupedal Movement Training specific exercises for certain athletic abilities can be explored further.
- More specific interventions might then follow the exact explanation of how such exercises bring about improvement offered by brain imaging or other physiological assessment tools
- Experimental science would be able to identify the most appropriate time, frequency, and level of difficulty of Quadrupedal Movement Training to maximize effects.

SUMMARY

The research highlights the role of QMT in substantially improving flexibility and joint range of motion in amateur tennis participants. QMT proven to be more effective as compared to conventional training as it advances more specific aspects of flexibility, tennis performance and injury prevention. Program led both statistically and clinically notable gains were observed in shoulder flexibility, sit and reach test, stroke precision, with the intervention group outperforming control group. Despite these results, constraints including restricted duration, narrow time frame and age-specific focus. Overall, QMT has the potential to provide benefits to tennis when integrated into conditioning routines aimed at enhancing flexibility and game performance

STATEMENT OF FUNDING

The author(s) reported no funding associated with the work featured in this dissertation. The author(s) further declare that there are no potential conflicts of interest, financial or otherwise, that could have influenced the outcomes, interpretation, or reporting of this work.

BIBLIOGRAPHIY/ REFERENCES

1. Xiao W. Exercise training and physical fitness in young tennis players: a systematic review. J Sports Med
Phys Fitness. 2022;62(3):377-85.

2. Luna-Villouta P, Sánchez-Muñoz C, Zabala M. Anthropometric characterization and physical performance by age and biological maturation in young tennis players. Int J Environ Res Public Health. 2021;18(4):1804.

3. Chian CC. Flexibility of internal and external glenohumeral rotation of junior female tennis players and its correlation with performance ranking. J Sports Sci. 2016;34(7):643-9.

4. Sangkaew T, Jitjumnong K, Chaiwanichsiri D. Analysis of ball speed and accuracy of groundstrokes on a clay court in young tennis players. Sports Biomech. 2024;23(1):77-89.

5. Huijgen BCH, Visscher C, Lemmink K. Technical characteristics as predictors of future performance in youth tennis players. J Sports Sci. 2021;39(8):905-12.

6. Buxton JD, Prins PJ. Effects of a novel quadrupedal movement training program on functional movement,
range of motion, muscular strength, and endurance. J Strength Cond Res. 2022;36(5):1452-60.

7. Yusuf M, Matthews M. Quadrupedal movement training improves markers of cognition and joint
repositioning. Hum Mov Sci. 2016;47:50-7.

8. Stecker E, Foster EB, Pascoe D. Test-retest reliability of hitting accuracy tennis test. Res Q Exerc Sport. 2011;82(2):236-42.

9. Salse-Batán A, Varela S. Reliability and validity of tests for assessing physical fitness in gymnasts. Int J
Sports Physiol Perform. 2022;17(4):505-12.

10. Ulbricht A, Fernandez-Fernandez J. Impact of fitness characteristics on tennis performance in elite junior
tennis players. Int J Sports Physiol Perform. 2016;11(8):905-12.

11. Hauschildt M, McQueen B, Stanford G. The core mobility series: a dynamic warm-up tool. Athl Train Sports Health Care. 2015;7(5):201-7.

12. Buxton J, Daugherty M, Grubbs R. Comparison of muscle activation during quadrupedal movement training
and traditional bodyweight exercises. Strength Cond J. 2024;46(2):37-45.

13. Layouni S, Dergaa I. Epidemiology of tennis-related injuries among competitive youth players in Tunisia.
Phys Ther Sport. 2025;62:15-22.

14. Xiao W, Bai X, Soh KG. Effects of functional training on tennis-specific physical fitness and functional movement in junior tennis players. Front Physiol. 2022;13:885946.

15. Fernandez-Fernandez J, Granacher U. Sequencing effects of neuromuscular training on physical fitness in
youth elite tennis players. Eur J Sport Sci. 2023;23(1):112-22.

16. Eckart AC. Quadrupedal movement training: a brief review and practical guide. Strength Cond J. 2023;
45(4):12-20.

17. Acurateța S. Youth tennis player serve accuracy with different racket variations. J Hum Kinet. 2020;72(1)
:87-94.

18 Oliveira V, Menayo R. Training tennis through induced variability and specific practice: effects on forehand approach shot accuracy. J Sports Sci. 2024;42(2):211-20.

19. Ayala F, Moreno-Pérez V. Acute and time-course effects of traditional and dynamic warm-up routines in
young elite junior tennis players. J Strength Cond Res. 2016;30(5):1234-42.

20. Johansson F, Cools A, Gabbett T. Association between spikes in training load and shoulder injuries in adolescent tennis players: the SMASH cohort study. Br J Sports Med. 2022;56(12):668-75.

21. International Tennis Federation. ITF Global Tennis Report 2021. London: ITF; 2021.

ANNEXURES

ANNEXURE 1-CONSENT FORM

I 25, aged years, confirm that I have understood about " EFFECT OF QUADRUPEDAL MOVEMENT

TRAINING ON FLEXIBILITY AND HITTING ACCURACY ON LAWN TENNIS ATHLETES: A RANDOMISED CONTROLLED TRIAL" as explained by Anushka and is as mentioned in his study which is taking place under the guidance Dr. Chinmaya Kumar Patra(PT), Principal, Abhinav Bindra sports medicine and research institute (ABSMARI) and co-guide by Dr. Anand Chandra Sahoo(PT), Assistant Professor, Abhinav Bindra sports medicine and research institute (ABSMARI). I understand that my participation is voluntary and

I'm free to withdraw at any time, without giving any reason. I understand that confidentiality will be maintained.

I voluntarily agree to and give my consent to be a part of the above-mentioned study.

Signature

Date

ANNEXURE 2- PARENTAL CONSENT FORM

Informed Consent form to participate in a clinical trial

Study Title: EFFECT OF QUADRUPEDAL MOVEMENT TRAINING ON FLEXIBILITY AND HITTING ACCURACY ON AMATEUR LAWN TENNIS PLAYERS

Study Number:

Subject ‘s Name: _____ Subject ‘s Initials: _____

Date of Birth / Age: _____

Address of the Subject_____

Qualification _____

Occupation: Student

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

_____

Please initial box

(Subject)

I confirm that I have read and understood the information sheet dated _____ [ ] for the above study and have had the opportunity to ask questions.

I understand that my participation in the study is voluntary and that he/she are [ ] free to withdraw at any time, without giving any reason, without my medical care or legal rights being affected.

The Ethics Committee and the regulatory authorities will not need my permission to look at my health records both in respect of the current study and any further research that may be conducted in relation to it, even if
he/she withdraw from the trial. I agree to this access. However, I understand that my identity will not be
revealed in any information released to third parties or published.

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)

I agree that I will take part in the above study. [ ]

Statement of Guardian obtaining consent :

I have carefully explained to the child taking part in the study what he/she can expect.

I certify that, to the best of my knowledge, the child understands the purpose, procedures, potential risks and benefits of the study and his/her rights as a participant.

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

_____

Date: _____/ ____/ _____

Signatory ‘s Name: _____

Signature of the Investigator:

_____

Date: Study Investigator ‘s Name: _____ANUSHKA_____

Signature of the Witness: _____

Date: _____/ _____/ _____

Name of the Witness: _____

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

ANNEXURE 3- ASSESSMENT FORM

Participant Information

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

Warm-Up Details

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

Stroke Direction & Shot Outcome

Pre – Intervention Post- Intervention

Stroke Direction	Shot No.	Target Zone Hit (1–12)	Zone Type (✓)	Shot Outcome (✓)	Notes		Stroke Direction	Shot No.	Target Zone Hit (1–12)	Zone Type (✓)	Shot Outcome (✓)	Notes
			☐ N ☐ D ☐ O	☐ In ☐ Error						☐ N ☐ D ☐ O	☐ In ☐ Error	
FH CC	1						FH CC	1				
FH CC	2						FH CC	2				
FH UTL	1						FH UTL	1				

Recovery Metrics

Pre – Intervention Post- Intervention

Direction	Time Between Shots (sec)	Recovery Position Maintained (✓)	Direction	Time Between Shots (sec)	Recovery Position Maintained (✓)
FH CC		□ Yes □ No	FH CC		□ Yes □ No
FH UTL		□ Yes □ No	FH UTL		□ Yes □ No
BH CC		□ Yes □ No	BH CC		□ Yes □ No
BH DTL		□ Yes □ No	BH DTL		□ Yes □ No

Shot Summary by Direction

Pre Intervention

Direction	Total Shots	In	Errors	Neutral	Defensive	Offensive
FH CC						
FH UTL						

Post - intervention

Direction	Total Shots	In	Errors	Neutral	Defensive	Offensive
FH CC						
FH UTL						

SIT AND REACH TEST

LEFT LEG

INTERVENTION GROUP	CONTROL GROUP

PRE - TEST	POST - TEST	PRE - TEST	POST - TEST

RIGHT LEG

INTERVENTION GROUP	CONTROL GROUP

PRE - TEST	POST - TEST	PRE - TEST	POST - TEST

SHOULDER

FLEXIBILITY TEST

RIGHT ARM

INTERVENTION GROUP.	CONTROL GROUP

PRE - TEST	POST - TEST	PRE - TEST	POST – TEST

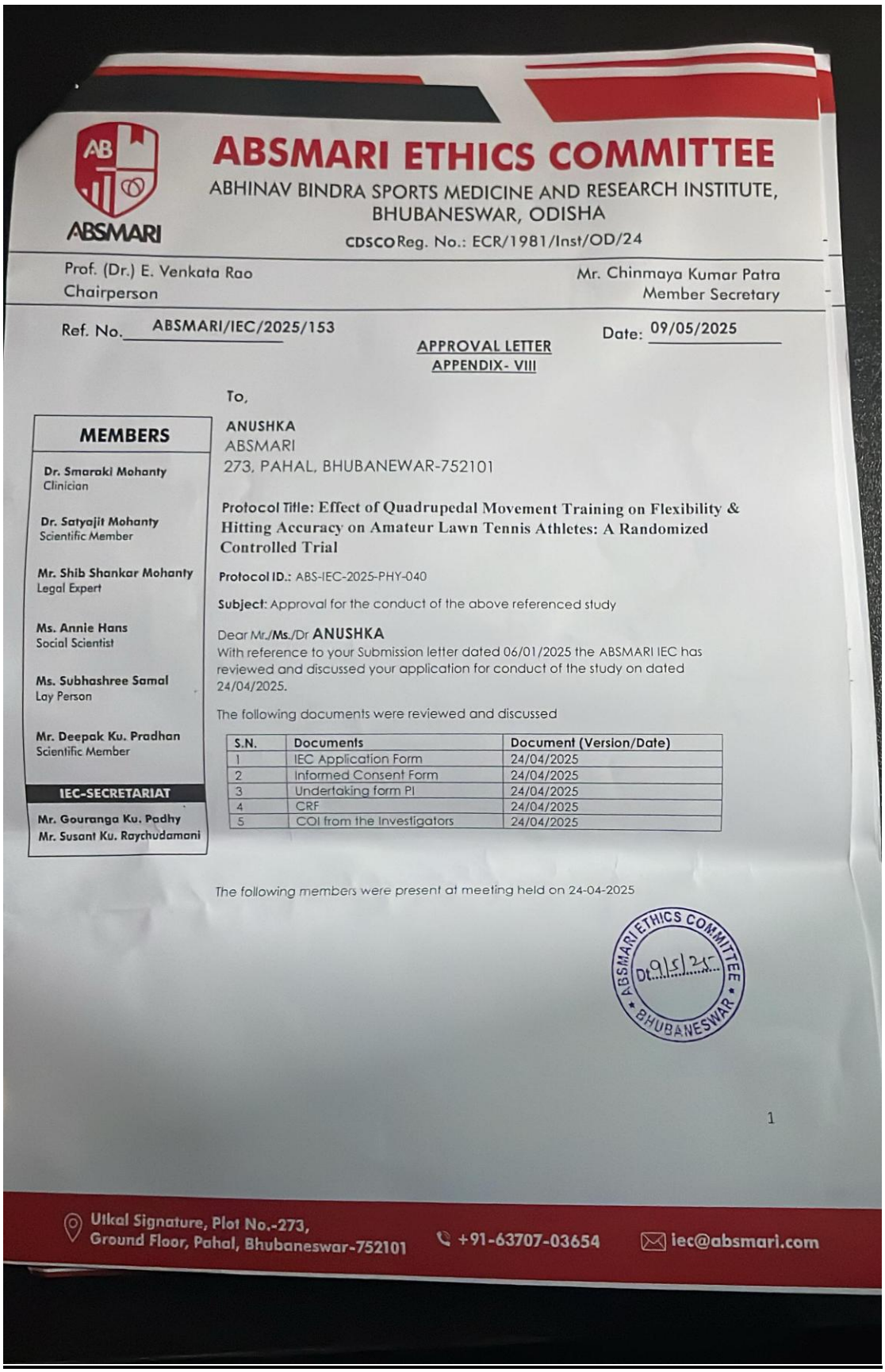
LEFT ARM

PRE - TEST	POST - TEST	PRE - TEST	POST – TEST

ANNEXURE 4- MASTER CHART

S.no	Name	Age	Gender	Group	Right Pre S&R	Left Pre S&	Right Post S&R	Left Post S&R	Pre FHAT	FHCC	Post FHAT	Pre FHULT	Post FHUL	Right Pre SI	Left Pre SF	Rigt
1	Tapan ku sahoo	16	Male	Intervention	3.2	2.5	5.5	5	7	11	8	10	6.5	4.5		
2	Aarav Mohapatra	17	Male	Intervention	3.4	2.6	6.2	5.3	8	12	9	13	6.2	4.4		
3	Lopamundra Swai	17	Female	Intervention	4.8	3.2	6.4	4.8	9	10	8	11	5.2	4.8		
4	Shruti Routray	15	Female	Intervention	4.4	3.8	6.4	4.2	11	12	10	13	6.5	4.4		
5	Devansh Panda	18	Male	Intervention	3.2	2.2	4.6	4.2	8	11	8	12	5.2	4.8		
6	Ayush Pattanaik	14	Male	Intervention	2.4	3.2	4.1	4.2	8	12	9	13	5.8	4.8		
7	Karan Rout	17	Male	Intervention	4.2	2.4	3.4	5.4	7	9	7	10	8.4	7.4		
8	Diya Choudhary	16	Female	Intervention	4.2	2.4	7.6	6.1	9	11	6	9	6.6	4.6		
9	Ishita Sahoo	15	Female	Intervention	3.2	2.4	5	4.2	8	9	9	10	4.8	6.2		
10	Vedant Pattnaik	18	Male	Intervention	3.3	2.6	4.8	4.4	9	11	9	12	6.2	4.4		
11	Kavya Padhy	14	Female	Intervention	3.2	2.5	5.2	5	8	11	8	10	6.5	4.5		
12	Arjun Nayak	14	Male	Intervention	3.2	2.4	4.8	4.2	9	10	8	10	6.4	4.8		
13	Kunal Samantaray	18	Male	Intervention	2.4	3.2	4.2	5	8	9	9	10	6.4	5.4		
14	Ankit Rout	15	Male	Intervention	1.8	2.5	2.2	3.5	8	9	9	10	3.6	4.2		
15	Priya Behera	14	Female	Intervention	1.4	1.2	2.8	2.4	8	11	9	12	4.2	3.6		
16	Sneha Sahoo	16	Female	Control	5	4	5.5	4.7	9	8	8	9	6	5.5		
17	Priyanshu Jena	14	Male	Control	5	5.5	4	4.5	8	8	8	9	5.4	5.3		
18	Priyanshi Mohanty	15	Female	Control	1.6	2.6	2	2.8	8	8	9	10	4.8	5.4		
19	Abhilipsa Behera	14	Female	Control	2.8	1.8	3.2	2.2	8	9	9	10	4.4	3.6		
20	Trishna Behera	14	Female	Control	1.6	2.4	1.8	2.6	8	9	9	10	4.2	3.8		
21	Anwesha Behera	17	Female	Control	5.4	4.6	5.8	5.4	8	8	9	10	6.8	5.6		
22	Rachita Mallick	18	Female	Control	5	5.5	4	5	6	8	8	9	5.5	6		
23	Ritesh Parida	17	Male	Control	3.2	1.5	4	2.5	10	12	8	10	2.4	2.4		
24	Brijesh Padhy	15	Male	Control	1	2	1.8	2.4	8	10	7	10	6.2	4.5		
25	Eashan Pattanik	15	Male	Control	1.6	2.6	2	2.8	8	8	9	10	4.8	5.8		
26	Ahana Nishank	14	Female	Control	5	5.5	4	4.5	8	8	8	9	5.4	5.3		
27	Riya Dash	14	Female	Control	4	5	5	5.5	9	7	8	9	5.5	5.8		
28	Biranchi Patra	16	Male	Control	5	5.5	5.2	5.5	8	10	9	9	5.5	5.6		
29	Subhashree Sahoo	17	Female	Control	4	5	5	5.5	10	11	11	11	2.6	2		
30	Bhavya Swain	17	Male	Control	5	5.5	4	4.2	6	7	7	9	1.8	2		

ANNEXURE 5- INSTITUTIONAL ETHICAL COMMITTEE CLEARANCE



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/2025/153

Date: 09/05/2025

APPROVAL LETTER
APPENDIX- VIII

To,

ANUSHKA
ABSMARI
273, PAHAL, BHUBANEWAR-752101

MEMBERS

- Dr. Smaraki Mohanty, Clinician
- Dr. Satyajit Mohanty, Scientific Member
- Mr. Shib Shankar Mohanty, Legal Expert
- Ms. Annie Hans, Social Scientist
- Ms. Subhashree Samal, Lay Person
- Mr. Deepak Ku. Pradhan, Scientific Member

IEC-SECRETARIAT

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

Protocol Title: Effect of Quadrupedal Movement Training on Flexibility & Hitting Accuracy on Amateur Lawn Tennis Athletes: A Randomized Controlled Trial

Protocol ID.: ABS-IEC-2025-PHY-040

Subject: Approval for the conduct of the above referenced study

Dear Mr./Ms./Dr **ANUSHKA**
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

ABSMARI ETHICS COMMITTEE * BHUBANESWAR * Dt. 9/5/25

1

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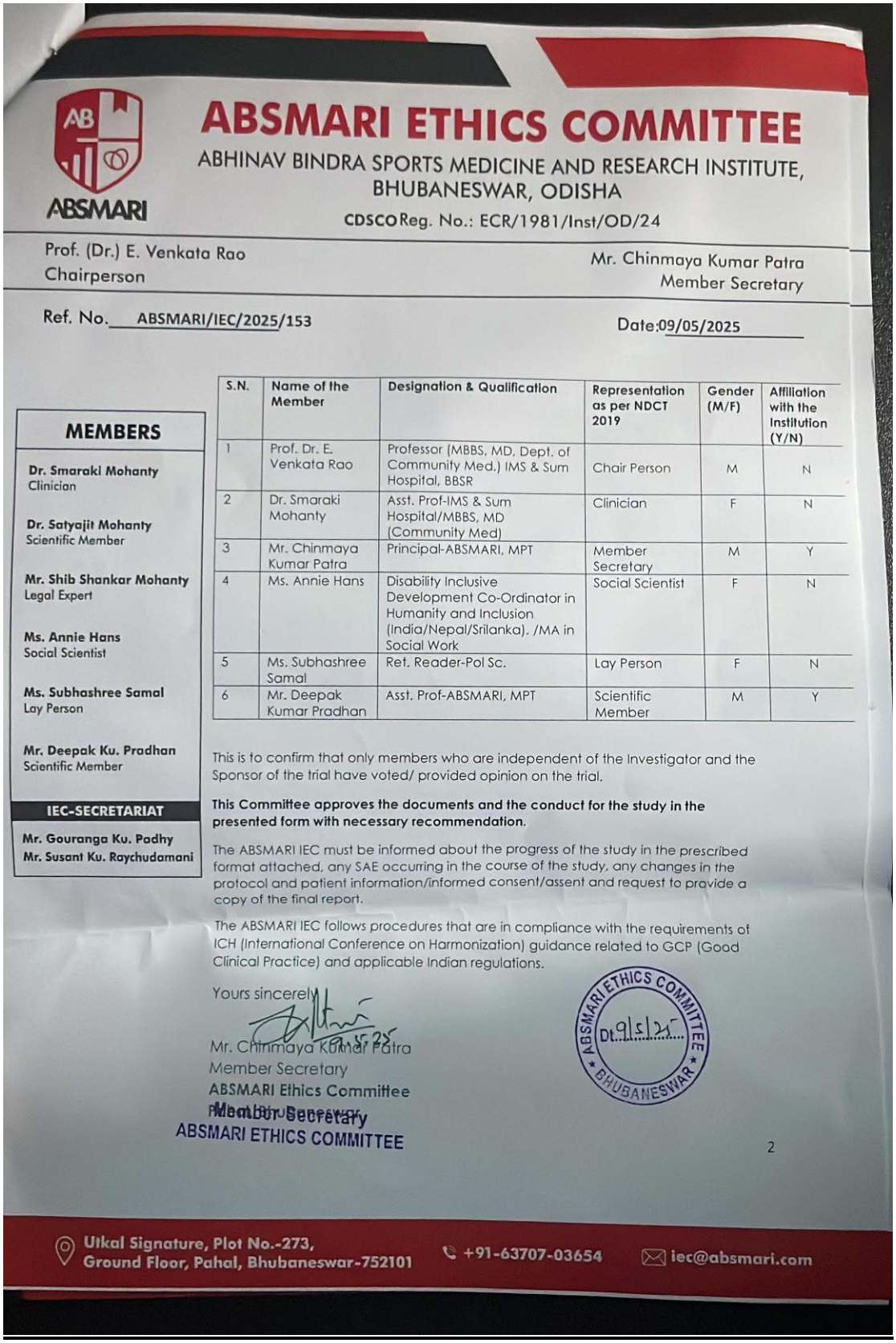

ABSMARI ETHICS COMMITTEE

ABHINAV BINDRA SPORTS MEDICINE AND RESEARCH INSTITUTE, BHUBANESWAR, ODISHA

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Prof. (Dr.) E. Venkata Rao
Chairperson

Mr. Chinmaya Kumar Patra
Member Secretary

Ref. No. ABSMARI/IEC/2025/153

Date: 09/05/2025

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

IEC-SECRETARIAT

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

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 in the prescribed format attached, 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

Member Secretary
ABSMARI ETHICS COMMITTEE

ABSMARI ETHICS COMMITTEE * BHUBANESWAR * Dt. 9/5/25

2

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ABHINAV BINDRA
Sports Medicine & Research Institute
A Unit of the Abhinav Bindra Foundation Trust
Recognised by DMET, Health & FW Dept., Govt. of Odisha, Affiliated to Utkal University
Recognised by Odisha State Council for Occupational Therapy and Physiotherapy
Affiliated to Odisha University of Health Sciences, Bhubaneswar

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principal@absmari.com

Date-15.05.205
Letter no-ABSMARI/ADMIN /2025/2598

TO WHOM SO EVER IT MAY CONCERN

This is to certify that Ms ANUSHKA is a bonafide student of ABSMARI M.P.T. 2ND Year batch of ABSMARI bearing Roll No ABS-MPT-2023-06 With reference to her requisition this institute has no objection in allowing her to carry out her research work as per the following details under the guidance of

Dr. Chinmaya Kumar Patra.

Ref: ABSMARI/IEC/2025/153

Title – "THE EFFECT OF QUADRUPEDAL MOVEMENT TRAINING ON FLEXIBILITY AND HITTING ACCURACY ON AMATEUR LAWN TENNIS PLAYER : A RCT."
Population - Amateur Lawn Tennis Player
study settings – Ace Base Tennis Academy

Duration – 4 weeks From - 30th may 2025 To – 30th June 2025

under the following conditions subject to thorough permission from their end -

1. She has to produce her official engagement plan issued by the study setting
2. She has to submit her certificate of attendance at last
3. She is liable to respond to institute when required
4. She must attend all examinations scheduled by the institution or university during this period
5. Daily report to Research- Guide and CC to Course-Coordinator is highly required

This NOC is effective From - 30th may 2025 To – 30th June 2025

CC –The Research Head, ABSMARI, The Course -Coordinator, The Research- Guide, Admin office

Principal, ABSMARI
15.5.25
PRINCIPAL, ABSMARI

ABHINAV BINDRA SPORTS MEDICINE AND RESEARCH INSTITUTE
ABSMARI
BHUBANESWAR

Utkal Signature, Plot No 273, NH-5, Patia, Bhubaneswar, 752101
Phone: 6370703650, 6370703651

ANNEXURE 6


airtel

*% 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.

Disclaimer
Our AI writing assessment is designed to help educators identify text that might be prepared by a generative AI tool. Our AI writing assessment may not always be accurate (i.e., our AI models may produce either false positive results or false negative results), so it should not be used as the sole basis for adverse actions against a student. It takes further scrutiny and human judgment in conjunction with an organization's application of its specific academic policies to determine whether any academic misconduct has occurred.

Frequently Asked Questions

How should I interpret Turnitin's AI writing percentage and false positives?
The percentage shown in the AI writing report is the amount of qualifying text within the submission that Turnitin's AI writing detection model determines was either likely AI-generated text from a large-language model or likely AI-generated text that was likely revised using an AI paraphrase tool or word spinner.

False positives (incorrectly flagging human-written text as AI-generated) are a possibility in AI models.

AI detection scores under 20%, which we do not surface in new reports, have a higher likelihood of false positives. To reduce the likelihood of misinterpretation, no score or highlights are attributed and are indicated with an asterisk in the report (*%).

The AI writing percentage should not be the sole basis to determine whether misconduct has occurred. The reviewer/instructor should use the percentage as a means to start a formative conversation with their student and/or use it to examine the submitted assignment in accordance with their school's policies.

What does 'qualifying text' mean?
Our model only processes qualifying text in the form of long-form writing. Long-form writing means individual sentences contained in paragraphs that make up a longer piece of written work, such as an essay, a dissertation, or an article, etc. Qualifying text that has been determined to be likely AI-generated will be highlighted in cyan in the submission, and likely AI-generated and then likely AI-paraphrased will be highlighted purple.

Non-qualifying text, such as bullet points, annotated bibliographies, etc., will not be processed and can create disparity between the submission highlights and the percentage shown.

2% 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

12 Not Cited or Quoted 2%
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

2% Internet sources
1% Publications
0% Submitted works (Student Papers)

Integrity Flags

1 Integrity Flag for Review

Hidden Text
12 suspect characters on 2 pages
Text is altered to blend into the white background of the document.

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.