

**“Correlation of Trunk Rotational Power  
with Forehand Smash Accuracy in Amateur  
Badminton Players – An Observational  
Study”**

by,

**Rushabh Chhangani**

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

In partial fulfilment  
of the requirements for the degree of  
**MASTER OF PHYSIOTHERAPY (M.P.T)**

In  
**SPORTS SCIENCES**

Under the guidance of  
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**ABHINAV BINDRA SPORTS MEDICINE & RESEARCH  
INSTITUTE**

Bhubaneswar, Odisha 2023-2025

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## ACKNOWLEDGEMENT

At the very outset, I express my deepest gratitude to Dr. Apjit S. Bindra, chairman, Mr. Abhinav A. Bindra, Founder, and Dr. Digpal Ranawat, Executive Director of Abhinav Bindra Sports Medicine and Research Institute, Bhubaneswar, for giving me this opportunity. I take this opportunity to convey my heartfelt gratitude to my guide **Dr. Asifuzzaman Shahriyar Ahmed (PT)**, Associate Professor, ABSMARI, for his valuable constant support, and feedback throughout the course of this study, along with suggestions that rendered in giving shape and coherence to this endeavour. Also, my co guide, **Dr. Gayatri Upasana Acharya (PT)** for her insight and encouragement helped me refine my research skills and navigate every challenge with confidence.

I am grateful to Ashish Agrawal's sports health academy, Nagpur for allowing me to carry out the clinical portion of this study, and to the staff for their cooperation and assistance during data collection.

I also acknowledge with a deep sense of reverence, my gratitude towards my parents, my family, and my friends who have always supported me morally and mentally. I would like to take this time to thank every participant who participated in this study for their kind cooperation and vital information without whom this research would not have been possible. And above all, I express my heartfelt gratitude to the Almighty for granting me the strength, patience, and perseverance to successfully complete this research work on time.

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## LIST OF ABBREVIATIONS USED

- cm – Centimetre
- df – Degrees of Freedom
- EMG – Electromyography
- ICC – Intraclass Correlation Coefficient
- IEC – Institutional Ethics Committee
- IQR – Interquartile Range
- kg – Kilogram
- MBT – Medicine Ball Toss
- m – Meter
- NOC – No Objection Certificate
- % – Percentage
- ROM – Range of Motion
- SD – Standard Deviation
- Sig. – Significance
- SPSS – Statistical Package for the Social Sciences

## **ABSTRACT**

### **Background:**

Trunk rotational power plays a critical role in generating explosive movements required in overhead sports like badminton. The forehand smash is a key offensive stroke that depends on coordinated trunk engagement for optimal performance. However, the extent to which trunk power contributes to smash score and accuracy remains under-investigated in amateur badminton players.

### **Objective:**

To evaluate the correlation between trunk rotational power and forehand smash performance, including smash score and accuracy percentage, in amateur badminton players.

### **Methods:**

This observational cross-sectional study included 29 amateur badminton players (18 males and 11 females) aged 18–25 years. Trunk rotational power was assessed using the medicine ball side toss test, and forehand smash performance was evaluated through a 10-smash accuracy test scored out of 30 points. Smash accuracy was calculated as a percentage of target hits. Spearman's rank correlation analysis was used to analyse the relationship between toss distance and both smash score and accuracy.

### **Results:**

A strong and statistically significant association was found between trunk rotational power and both forehand. smash score ( $\rho = 0.700$ ,  $p < 0.001$ ) and smash accuracy

percentage ( $\rho = 0.700$ ,  $p < 0.001$ ). Participants with higher toss distances demonstrated superior smash performance, indicating the importance of core muscle contribution.

**Conclusion:**

This investigation demonstrates a strong correlation between trunk rotational power and forehand smash performance in amateur badminton players. These findings support the incorporation of core-specific strength training in performance enhancement programs. The medicine ball toss test can function as an effective field-based screening tool for assessing trunk power and predicting stroke efficiency.

**Keywords:**

Amateur players; Badminton; Biomechanics; Core Strength; forehand smash; Kinematics; Medicine Ball Toss; Smash Accuracy; Trunk Power; Trunk Rotation;

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# **1. INTRODUCTION**

Badminton which is considered as a dynamic and high- intensity racket sport, needs remarkable speed, agility, co-ordination, and explosive power. Among its various techniques and pool of strokes this forehand smash stays as a decisive offensive action, which is mostly used to finish points. Forehand smash stroke depends particularly on the productive transmission of force through the kinetic chain that originates from the lower limb, and is transferred through the trunk and climaxing in the upper extremities. In such transfer, rotational power of the trunk plays a very important role as it acts as the central link connecting between lower body drive and execution of upper – limb. However, so far, the particular impact of trunk rotational power on the smash accuracy remains underexplored, especially in the amateur badminton players. As amateur players lack the optimum structured core development which can be a reason for suboptimal energy transfer and reduced effectiveness of stroke as compared to elite level athlete who often receive extensive biomechanical training to maximize the trunk contribution during play. Understanding about this dynamic of sport is very crucial for improving performance of the player along with it to reduce the risk of overuse injuries in less- trained athletes<sup>1,2</sup>.

Biomechanics of sports recognizes the trunk as the biomechanical bridge that creates and transfers the angular momentum during any rotational activities. Rotation of trunk involves combination of spinal and pelvic movement, that is activated due to the coordinated contraction of the core muscles including the obliques, multifidus and transversus abdominis<sup>1</sup>. This core musculature contributes to both areas that include postural stability and power production during the dynamic movements. For better velocity of smash optimum control over the direction and accuracy, effective and

efficient trunk velocity is crucial<sup>2,3</sup>. Injury risk is significantly increased along with decreased performance if there is reduced activation of trunk that can lead to compensatory movement in shoulder, elbow and wrist. Trunk plays dual role in both phases i.e. force generation while hitting smash and stabilization and deceleration after the smash is completed<sup>3,4</sup>. Professional Players usually train for core power and technique integration while amateur players often have variability in stroke precision usually due to underdeveloped neuromuscular coordination and trunk strength. In such population, correlating trunk function with performance outcomes like forehand smash accuracy becomes relevant. By understanding role of rotational power of trunk physiotherapists and coaches can design more efficient training protocols that will target neuromuscular recruitment patterns and movement sequencing while trunk rotation. This information is crucial for planning injury prevention strategies especially in amateur players who are more prone to musculoskeletal injuries during high velocity overhead movements<sup>5,6</sup>

In terms of measurement of performance, the medicine ball rotational toss test is widely used and accepted as a reliable and practical method to assess trunk rotational power<sup>4</sup>. This test simulates sports- specific trunk movement and allows for an objective measurement of rotational force through the distance a medicine ball is thrown. Various studies had validated this test in cricket, tennis and baseball population which demonstrates its correlation with throwing velocity and hitting power<sup>5,6</sup>. In case of badminton, this test can serve as a surrogate to evaluate involvement of trunk in explosive strokes like smash<sup>7,8</sup>. Also, medicine ball toss test is simple to implement in the field settings, with minimal requirement of equipment's and it can be repeated across sessions to monitor the progression of the training protocol, making it suitable for both areas i.e. both research and applied sports performance assessment.

On the other hand, the forehand smash accuracy test, often involving a target-based scoring system, is a sport-specific outcome that reflects both neuromuscular coordination and biomechanical efficiency<sup>9</sup>. Accurate execution of the forehand smash depends on several factors including approach speed, trunk rotation, shoulder alignment, wrist control, and visual tracking. Since the trunk governs mid-body control and force transfer, its power likely influences the precision with which an athlete can execute an overhead shot<sup>10,11</sup>. Moreover, accuracy is not solely dependent on muscle strength but also on timing, segmental sequencing, and anticipatory postural adjustments, all of which are enhanced by trunk conditioning. Integrating both measurement tools—the rotational medicine ball test and the target-based smash test—offers a comprehensive approach to linking physical capacity with sport-specific skill performance.

Literature from sports like baseball, handball, and tennis also consistently underscores the importance of trunk power for stroke accuracy and injury prevention. For instance, a study by Hsieh and colleagues<sup>12,23,14</sup> showed that core strength training improved not only serve velocity but also directional control in collegiate tennis players. Similarly, Lehman et al.<sup>14</sup> emphasized the role of core activation patterns in maintaining dynamic postural control, directly linked to shot precision. Badminton-specific studies, however, have focused more on biomechanics of elite players, ignoring trunk contributions in amateur populations<sup>15,16</sup>. Expanding research into amateur cohorts is important because performance limitations in these athletes often result from incomplete skill acquisition and insufficient core strength rather than lack of technique, making trunk-targeted interventions highly relevant for training programs.

Rotational sports training literature supports the concept that increased trunk rotational power improves kinetic sequencing, reduces energy leakage across segments, and

enhances precision<sup>17,18,19</sup>. In this context, medicine ball throws have shown high correlation with performance metrics like punch force in boxing<sup>20,21</sup>, bat speed in baseball<sup>22</sup>, and serve accuracy in tennis<sup>23,24</sup>. Given the similar mechanics, such findings can logically be extended to badminton's forehand smash. Additionally, improving trunk power can enhance dynamic balance, postural control, and reactive agility, all of which are essential for executing smashes effectively in fast-paced rally situations.

From a rehabilitation and physiotherapy perspective, strengthening the trunk not only enhances performance but also reduces compensatory strain on peripheral joints. Overhead athletes with weak core musculature are more susceptible to shoulder impingement, lumbar instability, and elbow overuse injuries due to altered force distribution<sup>25</sup>. Evidence also supports the idea that improved core function aids in balance, reactive strength, and neuromuscular control—all of which contribute to shot stability and accuracy<sup>26,27,28</sup>. Integrating trunk conditioning into training and rehabilitation programs therefore has dual benefits: enhancing performance and minimizing injury risk, a particularly important consideration for amateur players with limited exposure to structured training.

Despite this biomechanical rationale, studies directly linking trunk power to accuracy in badminton remain sparse. A gap exists in field-based, observational research that simultaneously examines both these parameters in amateur populations using simple, non-invasive, and repeatable tests. By selecting two practical outcome measures—the medicine ball side toss test and a target-based forehand smash accuracy test—this study aims to fill that gap. Conducting such research will provide data-driven guidance for coaches, physiotherapists, and sports scientists to optimize training interventions.

The hypothesis proposed is that higher trunk rotational power will either correlate positively with better forehand smash accuracy or may not. This finding, if confirmed, would validate the use of trunk power assessments in routine badminton training and support the development of targeted trunk conditioning protocols in amateur players. Moreover, such a relationship would have practical implications for injury prevention, talent development, and sports-specific rehabilitation, where core strengthening could be prescribed not only for general fitness but also to directly impact performance variables like smash precision. This approach aligns with the contemporary trend of integrating functional biomechanics into sports training and clinical physiotherapy

28,29,30

## **Need of the Study**

The forehand smash is one of the most powerful and decisive strokes in badminton, relying heavily on the coordination and force generated through the trunk and core muscles. While amateur players often train for upper limb strength and technique, the contribution of trunk rotational power is frequently overlooked.

Effective trunk rotation enables better force transfer through the kinetic chain, improving smash speed and accuracy. However, limited research has focused on the relationship between trunk power and stroke accuracy, especially in amateur badminton players. This creates a gap in understanding how core-specific performance influences gameplay.

Identifying this correlation can help coaches and physiotherapists design more targeted and efficient training programs that improve shot accuracy, enhance performance, and reduce injury risk. This study is therefore essential to determine whether increasing trunk rotational power contributes significantly to better forehand smash accuracy in amateur players.

## **2. AIM AND OBJECTIVES**

## **Aim of the Study**

To determine the relationship between trunk rotational power and forehand smash accuracy in amateur badminton players.

## **Objectives of the Study**

- To assess trunk rotational power in amateur badminton players using the Medicine Ball Side Toss Test.
- To evaluate forehand smash accuracy using the Overhead Forehand Smash Accuracy Test.
- To analyse the correlation between trunk rotational power and forehand smash accuracy.
- To provide recommendations for core training strategies to improve forehand smash performance based on study findings.

### **3. HYPOTHESIS**

**Null Hypothesis (H<sub>0</sub>):**

There is no significant correlation between trunk rotational power and forehand smash accuracy in amateur badminton players.

**Alternative Hypothesis (H<sub>1</sub>):**

There is a significant positive correlation between trunk rotational power and forehand smash accuracy in amateur badminton players.

## **4. REVIEW OF LITERATURE**

1. **Sell MA. (2013). The Development and Assessment of Core Strength Clinical Measures: Validity and Reliability of Medicine Ball Toss Tests. Master's Thesis, University of Pittsburgh.**

This study investigated the validity and reliability of three medicine ball toss (MBT) tests—forward, backward, and rotational—as clinical measures of core strength. Results showed excellent test–retest reliability (ICC ranging from 0.835 to 0.909,  $p < 0.001$ ), but poor concurrent validity with isokinetic strength measures (non-significant Pearson correlations). The findings suggest that MBT tests are reliable but not valid indicators of core strength when compared against isokinetic dynamometry. The author concluded that while MBT tests may serve as consistent tools for monitoring performance, modifications are necessary to improve their validity. Future research should focus on refining these tests to maintain reliability while enhancing validity.<sup>1</sup>

2. **Indora et al., 2022; Correlation of Upper Limb Explosive Power with Smash Velocity and Performance in Badminton Players: A Cross-sectional Study**

The study examined the relationship between upper limb explosive power and smash velocity in young badminton players and found a significant positive correlation. The authors concluded that greater upper limb explosive power contributes to enhanced smash performance, highlighting the need for sport-specific power training in badminton. This is relevant to the present study as it supports the role of physical attributes in determining stroke performance.<sup>2</sup>

3. **Kibler et al. (2006), in their paper titled “The role of core stability in athletic function” published in Sports Medicine**, reviewed the importance of core musculature in athletic performance. The authors aimed to highlight how trunk

function contributes to efficient energy transfer during dynamic movements. Drawing from clinical and biomechanical evidence, they explained that over 50% of force in overhead strokes is generated from the trunk and that poor stability reduces kinetic chain efficiency. They concluded that trunk/core assessment is critical for overhead sports. This reinforces the present study's aim of analysing trunk rotational power as a determinant of forehand smash accuracy in badminton <sup>3</sup>.

4. **Hibbs et al. (2008) published a review titled “Optimizing performance by improving core stability and core strength” in Sports Medicine** with the purpose of exploring the biomechanical and physiological foundations of trunk training. Through critical synthesis of experimental and applied sport studies, they demonstrated that enhanced trunk strength improves dynamic balance, coordination, and power transfer. The authors concluded that trunk stability is vital across rotational sports and directly supports technical performance. Their findings justify the assessment of trunk rotational power in badminton players for its impact on stroke execution and accuracy <sup>4</sup>.
5. **Phomsoupha and Laffaye (2015), in their comprehensive review “The science of badminton: game characteristics, anthropometry, physiology, visual fitness and biomechanics” published in Sports Medicine**, investigated physiological, technical, and biomechanical determinants of badminton performance. The authors emphasized that efficient kinetic chain function, particularly trunk and pelvic rotation, is essential for explosive overhead strokes such as the forehand smash. They concluded that core strength and trunk control are major contributors to shuttle velocity and accuracy. This review provides

direct sport-specific support for examining trunk power in badminton smash performance <sup>8</sup>.

6. **Zhang et al. (2016) conducted a biomechanical study titled “The influence of X-factor (trunk rotation) and experience on the quality of the badminton forehand smash” published in the Journal of Human Kinetics.** Their objective was to investigate the role of trunk rotation angle and player experience on smash outcomes. Using 3D motion capture in skilled and novice players, they found that greater trunk rotation (X-factor) was significantly associated with higher shuttle speeds and more efficient kinetic sequencing. They concluded that trunk rotation strongly influences smash power and precision. This directly validates the present study’s focus on trunk rotational power in amateur players <sup>19</sup>.
7. **Ramasamy et al. (2024) in their article “Kinetic and kinematic determinants of shuttlecock speed in the forehand jump smash performed by elite male Malaysian badminton players” published in Sports Biomechanics,** aimed to identify biomechanical predictors of shuttle speed. Using synchronized force plates and motion analysis, they showed that trunk rotation velocity, pelvic ROM, and ground reaction forces significantly correlated with smash speed. The authors concluded that trunk mechanics are essential to overhead power generation. Their findings confirm the centrality of trunk power to smash performance, supporting its assessment in amateur contexts <sup>22</sup>.
8. **Szymanski et al. (2004) studied the “Effect of twelve weeks of medicine ball training on high school baseball players” published in Medicine & Science**

**in Sports & Exercise.** The purpose was to determine whether trunk-focused rotational medicine ball training improves performance. A 12-week intervention was conducted, and results showed significant increases in throwing and batting velocity. They concluded that medicine ball training effectively develops rotational trunk power transferable to sports. This validates the use of medicine ball tosses as outcome measures for trunk rotational power in badminton <sup>5</sup>.

9. **Genevois et al. (2013) conducted a study titled “Effects of two training protocols on the forehand drive performance in tennis” published in the Journal of Strength & Conditioning Research, aiming to compare effects of core-focused vs. traditional training.** Using a 6-week intervention, they found significant improvements in forehand velocity after medicine ball and core training. They concluded that trunk training enhances racket stroke velocity. This evidence from tennis underlines the transferable impact of trunk training on badminton smash performance <sup>6</sup>.
10. **Fernández-Fernández et al. (2013) in their study “Effects of a 6-week junior tennis conditioning program on serve velocity” published in the Journal of Strength & Conditioning Research,** investigated the effects of integrated core and medicine ball exercises. Junior players who completed the program showed significant increases in serve velocity compared with controls. The authors concluded that trunk-focused training improves stroke velocity and neuromuscular control. This supports the relevance of trunk power in badminton smash accuracy <sup>15</sup>.
11. **Nesser et al. (2008), in their study “The relationship between core stability and performance in Division I football players” published in the Journal of**

Strength & Conditioning Research, sought to identify correlations between core stability and athletic performance. Athletes were assessed using core endurance and medicine ball throws, with strong associations observed between trunk strength and power outputs. They concluded that trunk stability measures predict sport performance. This provides indirect but relevant support for trunk assessments in badminton <sup>14</sup>.

12. **Lehman et al. (2005) published “Trunk muscle activity during bridging exercises on and off a Swiss ball” in Chiropractic & Osteopathy**, with the goal of comparing muscle activation across exercise conditions. Using EMG, they showed that unstable surfaces significantly increased activation of obliques and spinal stabilizers. They concluded that exercise modality affects trunk muscle recruitment, with implications for rotational strength. This supports the biomechanical basis of trunk power assessment for badminton smashes <sup>11</sup>.

13. **Behm et al. (2010) in their review “The use of instability to train the core musculature” published in Applied Physiology, Nutrition, and Metabolism, aimed to summarize evidence on instability training.** They reported that unstable surface training increased neuromuscular recruitment and core endurance, translating to improved sport-specific control. The authors concluded that such training is effective for enhancing trunk coordination. This indirectly supports the role of core neuromuscular function in controlling smash accuracy <sup>11</sup>.

14. **Willson et al. (2005) in their article “Core stability and its relationship to lower extremity function and injury” published in the Journal of the American Academy of Orthopaedic Surgeons, reviewed biomechanical**

**evidence of trunk control.** They found that strong trunk stability improves lower limb alignment and reduces injury risk, thereby enhancing functional performance. They concluded that trunk control is integral to dynamic movements. Though focused on the lower body, their findings reinforce trunk power's influence on coordinated stroke accuracy in badminton <sup>10</sup>.

15. **Sayers and Bishop (2017) presented “Reliability of a new medicine ball throw power test” in the Journal of Strength & Conditioning Research, with the objective of validating field tests of power.** They performed test–retest reliability trials showing high reproducibility of medicine ball throw measures. They concluded that medicine ball tests are reliable for measuring power output. This supports their use for quantifying trunk rotational power in badminton players <sup>20</sup>.

16. **Escamilla et al. (2009), in their review “Shoulder muscle recruitment patterns and related biomechanics during overhead sports actions” published in the Journal of Strength & Conditioning Research,** analyzed EMG and biomechanical studies across sports such as tennis, baseball, and volleyball. They highlighted that trunk rotation timing critically affects shoulder activation and resultant stroke velocity. They concluded that proper trunk function is necessary for optimizing overhead performance. This provides cross-sport justification for measuring trunk rotational power in badminton <sup>12</sup>.

17. **Landlinger et al. (2010) in their study “Kinematic differences of elite and sub-elite tennis players in the forehand stroke” published in the Journal of Sports Science & Medicine,** aimed to identify segmental contributors to racket speed. Using 3D analysis, they found that axial trunk rotation and pelvis-

shoulder separation were primary factors distinguishing elite from sub-elite strokes. They concluded that trunk rotation is a central factor in power and timing. This supports the role of trunk power in differentiating smash accuracy levels in badminton players<sup>22</sup>.

18. **Hardy et al. (2025)**, in the paper titled “**Criterion validity and reliability of a new medicine ball rotational power test**” published in *Journal of Strength & Conditioning Research*, assessed a novel field method for measuring rotational trunk power. The study aimed to validate two medicine ball rotational tests—one measuring maximum velocity via radar (MB vel) and one measuring maximum distance (MB dis)—against 3D motion-capture as the gold standard. Fifteen professional female cricketers performed 24 maximal throws each, and results showed MB vel to have excellent accuracy (ICC = 0.97) and reliability (ICC = 0.94), whereas MB dis performed poorly in both domains. The study concluded MB vel is a valid and reliable field test for rotational power assessment. This directly supports using medicine ball rotational velocity testing as a meaningful, practical measure of trunk rotational power in your observational study of badminton smash accuracy<sup>9</sup>.
19. **Freeston et al. (2025)** (same study expanded), in the same article titled “**Criterion validity and reliability of a new medicine ball rotational power test**”, reinforced the above findings. Using the same methods and sample, the authors concluded consistency across dominant and non-dominant sides and confirmed the MB vel test’s precision and reproducibility via radar and motion-capture comparison. This further validates the MB vel protocol for trunk rotational power measurement in sports contexts, including badminton smash research<sup>18</sup>.

## **5. METHODOLOGY & PROCEDURE**

## METHODOLOGY

**Study Design-** observational correlation study

**Study Setting** - The study was conducted in a controlled indoor badminton training facility in the ASHA -Ashish Agrawals sports health academy, Nagpur..

**Sampling type-** purposive sampling

**Sample size** -

$$n = \frac{Z^2 \cdot p \cdot (1 - p)}{d^2}$$

n = required sample size

Z = Z-score corresponding to the desired confidence level (1.96 for 95% confidence)

p = expected proportion (prevalence) of the outcome

d = acceptable margin of error

= 29 amateur badminton players

**Study Duration-**Data collection was carried out over a period of 4 weeks.

**Ethical Considerations-**Prior to initiation, the study protocol was reviewed and approved by the Institutional Ethics Committee(ABSMARI/IEC/2025/154). All participants provided written informed consent prior to participation in the study.

## **Inclusion and exclusion criteria.**

### **Inclusion Criteria-**

- Male and female amateur badminton players aged 18–25 years
- Individuals free from current musculoskeletal injuries or recent surgeries
- Willingness to participate with signed informed consent

### **Exclusion Criteria**

- Players with any history of acute or chronic spinal, shoulder, or lower limb injury
- Presence of neurological disorders affecting motor performance
- Previous core muscle training interventions in the last 3 months
- Involvement in competitive tournaments within 48 hours prior to testing

### **Study Tools and Equipment**

- Medicine Ball (3 kg) – used for trunk rotational power testing.
- Measuring Tape (in meters) – to measure toss distance.
- Standardized Badminton Forehand Smash Accuracy Setup – includes a marked court and scoring targets.
- Data Recording Sheet – to capture all measurements.
- Stopwatch and Chalk – for court markings and toss start points.

## PROCEDURE

Each participant underwent a single testing session consisting of two parts:

### 1. Trunk Rotational Power Assessment

- The medicine ball rotational toss test was used to measure trunk power.
- Participants were in tall kneeling position, held a 3 kg medicine ball at chest level, and performed a rotational throw (side toss) using their dominant side.
- The toss distance (in meters) was measured from the release point to the first contact of the ball on the floor.
- Three trials were given, and the best of three distances was recorded.

### 2. Forehand Smash Performance Testing

- Players performed 10 standardized forehand smashes aimed at marked target zones on the opposite court.
- Each smash was scored based on a predetermined scoring chart:
  - Red colour zone = 3 points
  - Blue colour zone = 2 points
  - Yellow colour = 1 point
- The total smash score (out of 30) was calculated.
- Additionally, smash accuracy (%) was computed using the formula:

Accuracy (%) = (Number of successful hits) / total hits i.e.  $30 \times 100$

## Flow chart of Methodology

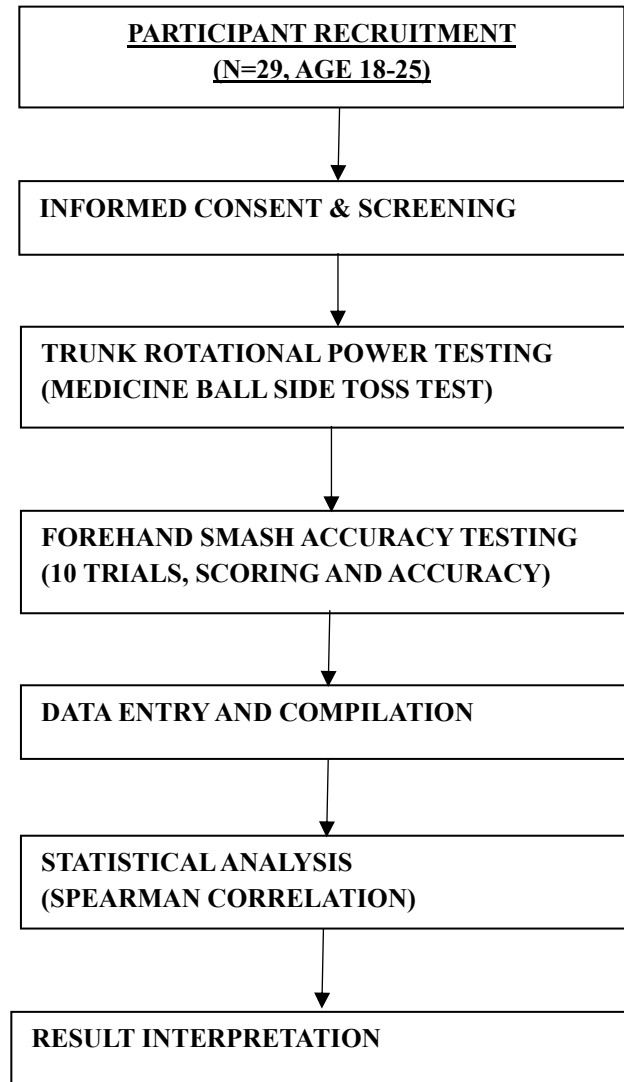


Figure- 1 . Flowchart of methodology of the study



Figure 2 : Participant Performing Side Medicine Ball Toss Test



Figure 3 : Participant Performing Forehand Smash Accuracy Test

## **6.STATISTICAL ANALYSIS**

The collected data were entered into Microsoft Excel 2021 and analysed using IBM SPSS Statistics Version 27. Descriptive statistics, including mean, standard deviation (SD), median, and range, were calculated for all variables to summarize participant characteristics and outcome measures.

To determine the relationship between trunk rotational power (assessed by medicine ball toss distance) and forehand smash performance (score and accuracy percentage), Spearman's rank correlation coefficient ( $\rho$ ) was employed, as the data were not normally distributed. A p-value of less than 0.05 ( $p < 0.05$ ) was considered statistically significant.

All statistical analyses were performed in accordance with standard procedures for observational correlation studies. Graphical representations, including scatter plots, were generated to visualize the relationships between the variables.

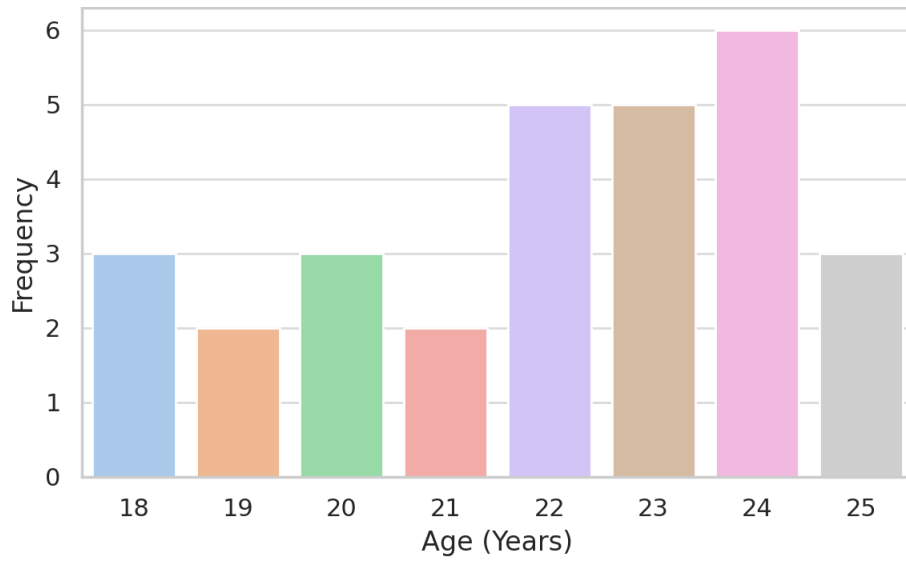
## **7.RESULTS**

### **Baseline Characteristics of Participants**

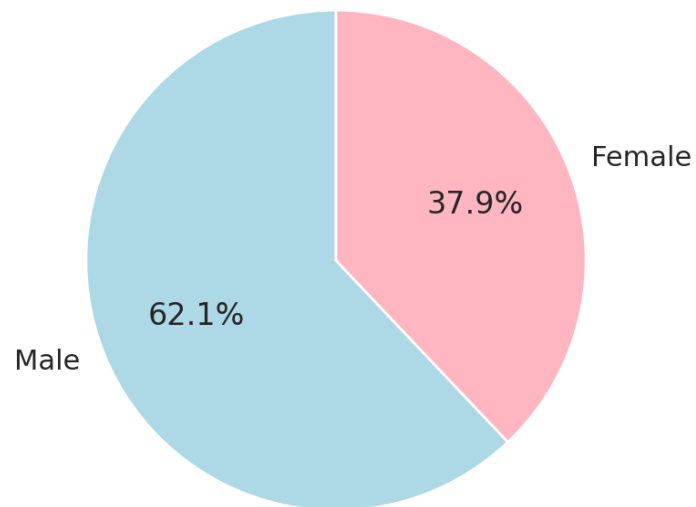
A total of 29 participants were included in the study, comprising 18 males (62.1%) and 11 females (37.9%). The mean age of the participants was  $22.07 \pm 2.23$  years, ranging from 18 to 25 years. With regard to hand dominance, 21 participants (72.4%) were right-handed and 8 participants (27.6%) were left-handed.

<b>Age</b>	<b>Frequency</b>
18	3
19	2
20	3
21	2
22	5
23	5
24	6
25	3

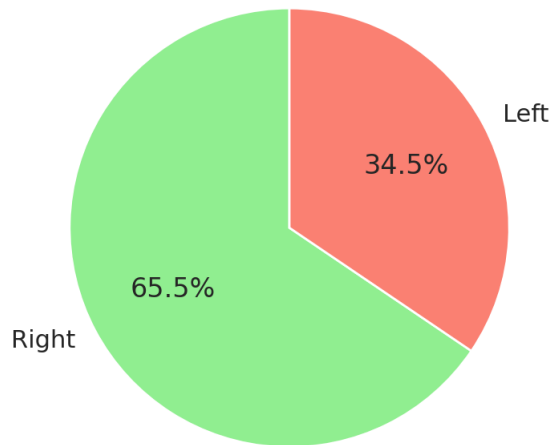
Table 1: Age Distribution of Participants



Graph 1: Age Distribution of Participants



Graph 2: Gender Distribution of Participants

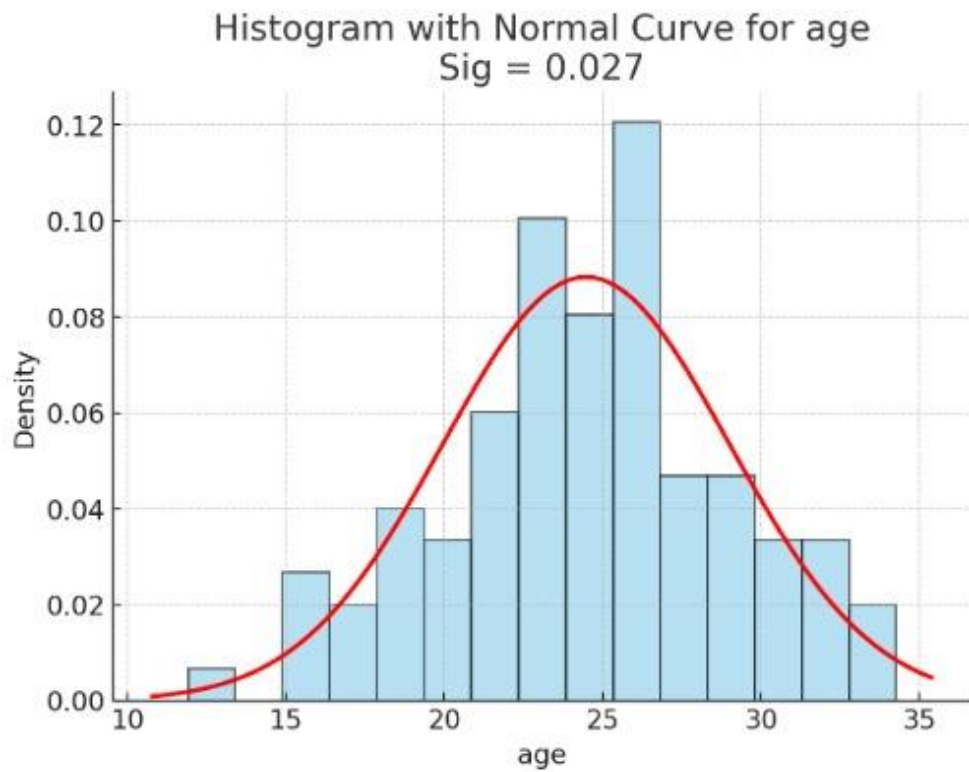


Graph 3: Hand Dominance Distribution of Participants

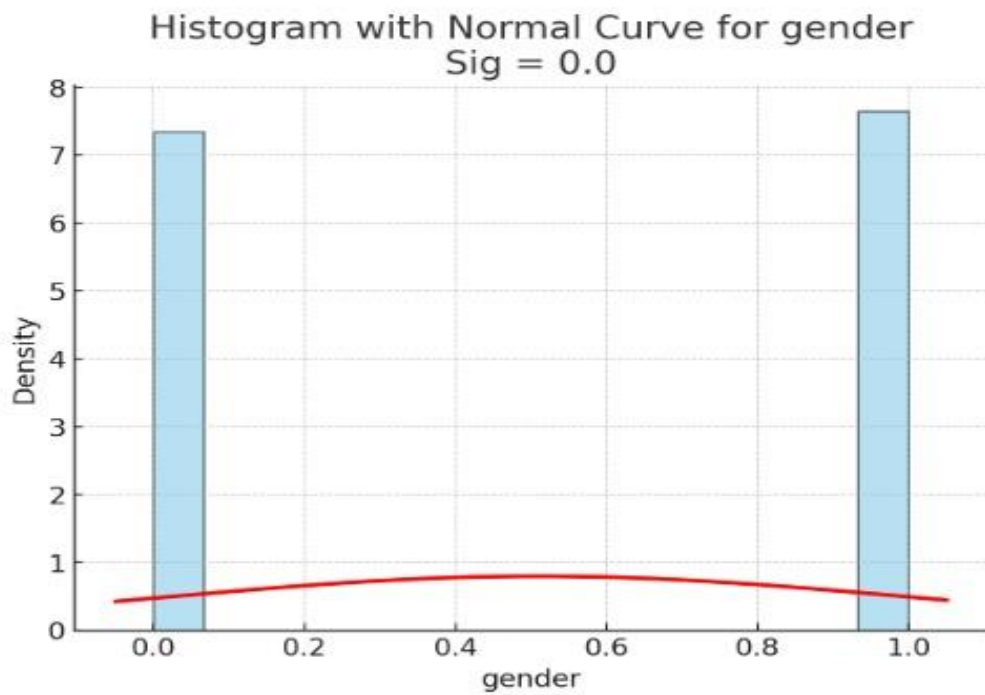
Variable	Statistic	df	Sig.
age	.918	29	.027
gender	.617	29	.000
dominance	.561	29	.000
Medicine ball toss test	.969	29	.521
Smash accuracy	.906	29	.014
Accuracy percentage	.906	29	.014

Table2- Normality Of Variables

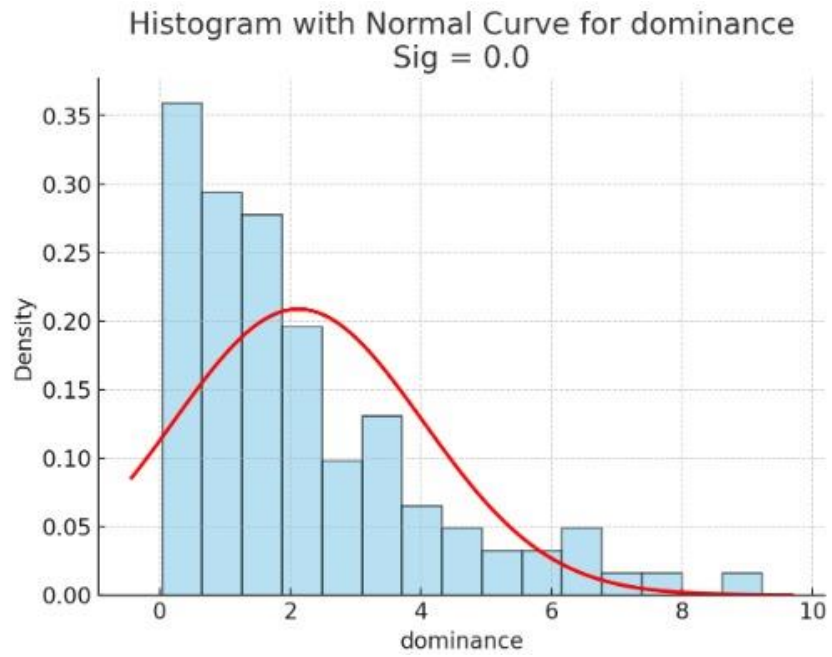
- Normally distributed: Medicine ball toss test.
- Not normally distributed: Age (per Shapiro–Wilk), Smash accuracy, Accuracy percentage.



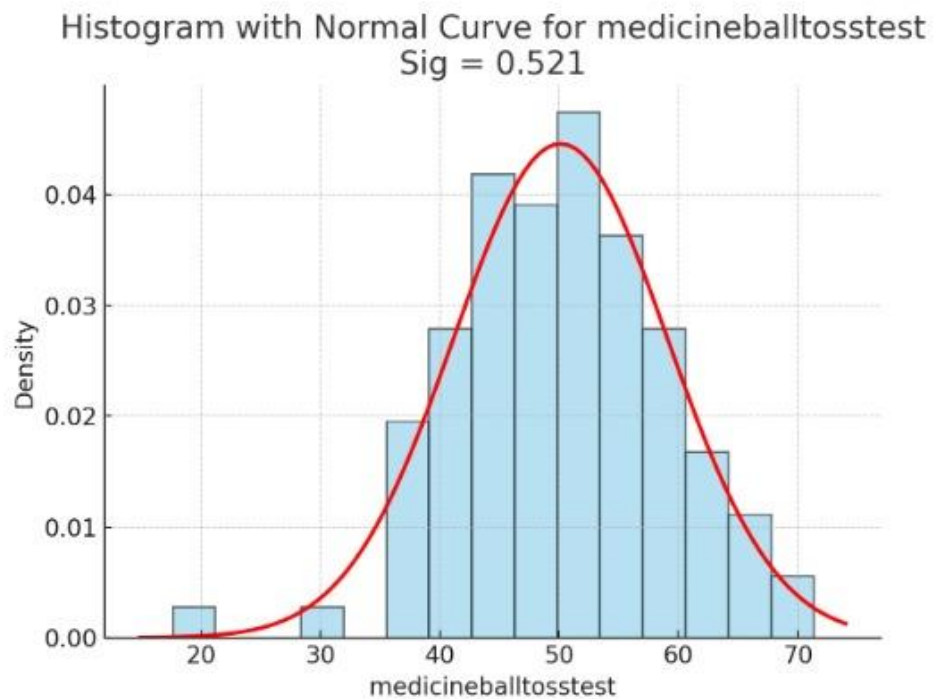
Graph 4.a.- normality of variables – bell curve layout for age



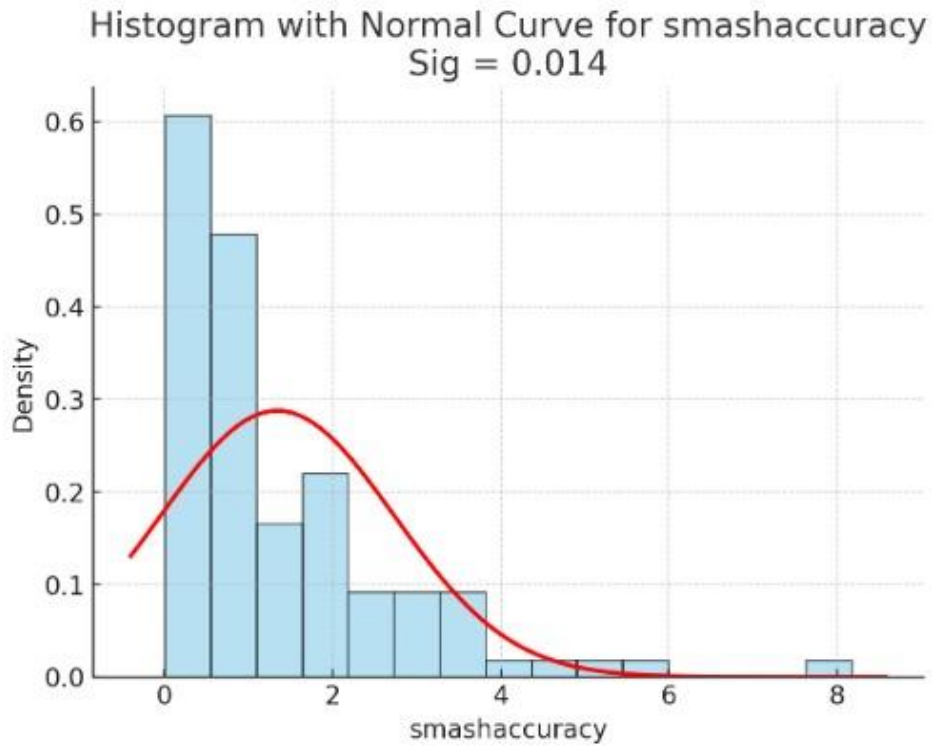
Graph 4.b.- normality of variables – bell curve layout for gender



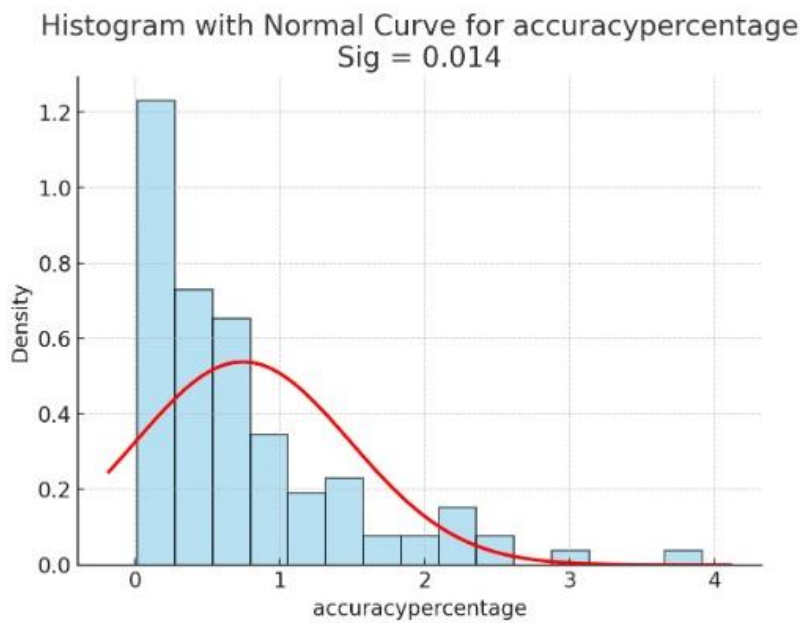
Graph 4.c.- normality of variables – bell curve layout for hand dominance



Graph 4.d.- normality of variables – bell curve layout for medicine ball toss test



Graph 4.e.- normality of variables – bell curve layout for smash accuracy



Graph 4.f.- normality of variables – bell curve layout for smash accuracy percentage

### Descriptive Statistics

<b>Variable</b>	<b>Mean <math>\pm</math> SD</b>	<b>Median (IQR)</b>	<b>Min–Max</b>
<b>Age</b>	22.00 $\pm$ 2.20	22.0 (20.0 – 24.0)	18 – 25
<b>Gender</b>	1.28 $\pm$ 0.45	1.0 (1.0 – 2.0)	1 – 2
<b>Dominance</b>	1.38 $\pm$ 0.49	1.0 (1.0 – 2.0)	1 – 2
<b>Medicine Ball Toss Test (m)</b>	4.40 $\pm$ 0.11	4.56 (3.87 – 4.96)	3.00 – 5.56
<b>Smash Accuracy (score)</b>	18.89 $\pm$ 0.45	18.0 (17.0 – 20.0)	16 – 25
<b>Accuracy Percentage (%)</b>	$\sim$ 62.9 $\pm$ 1.50	60.0 (56.7 – 66.7)	53.3 – 83.3

Table 3 - presents the mean, standard deviation, minimum, and maximum values for toss distance, forehand smash score, and smash accuracy.

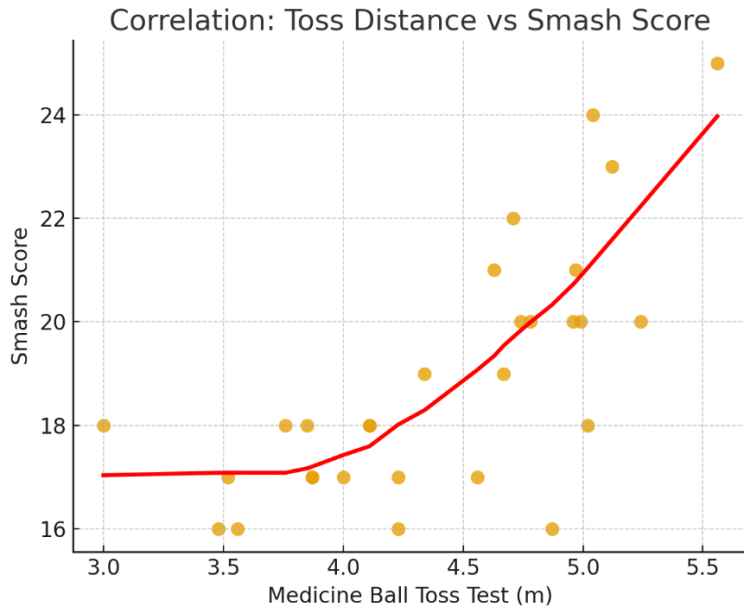
### Correlation Analysis

The Spearman's rank correlation analysis revealed a **very strong positive and statistically significant correlation** between medicine ball toss distance and both smash score ( $\rho = 0.700$ ,  $p < 0.001$ ) and smash accuracy percentage ( $\rho = 0.700$ ,  $p < 0.001$ ).

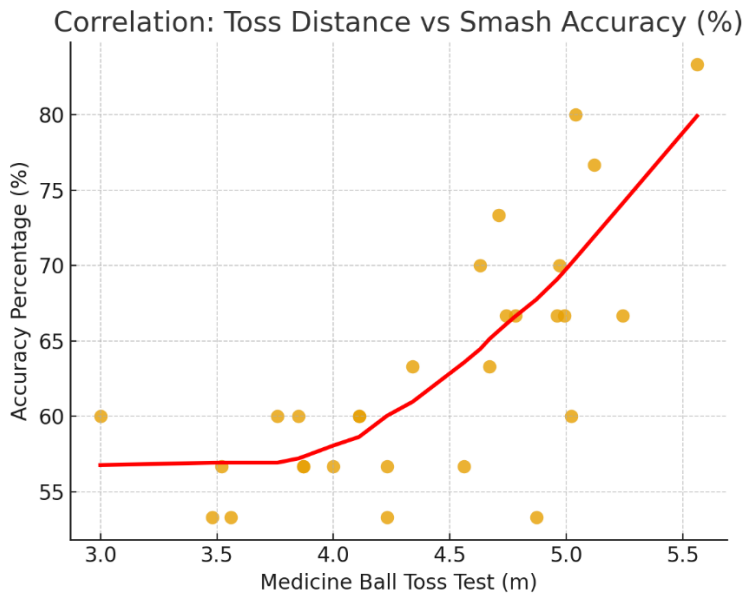
This indicates that participants with greater trunk rotational power (longer toss distances) tended to achieve both higher smash scores and greater accuracy percentages in their forehand smashes. These findings suggest that rotational core strength and power are directly linked to performance in badminton-specific overhead strokes.

Variable Pair	$\rho$ -value	p-value	Interpretation
Toss Distance vs Smash Score	0.700	< 0.001	Very strong positive, significant
Toss Distance vs Smash Accuracy	0.700	< 0.001	Very strong positive, significant

Table 4: Correlation Coefficients



Graph 5(a): Scatter Plot – Toss Distance vs Smash Score



Graph 5(b): Scatter Plot – Toss Distance vs Smash Accuracy

The scatter plot shows a strong positive relationship between toss distance and smash accuracy. Participants with greater trunk rotational power (longer toss distances) tend to have higher smash accuracy, supporting the significant correlation ( $\rho = 0.700$ ,  $p < 0$

## **8.Discussion**

The Present research sought to investigate the relationship between trunk rotational power and The forehand smash performance among amateur badminton players who are 18 to 25 years old. It was hypothesized that increased trunk rotational power would be positively correlated with better forehand smash performance regarding accuracy. The findings upheld this hypothesis and demonstrated very strong and highly notable positive correlation ( $r = 0.702$ ,  $p < 0.001$ ) between smash accuracy and medicine ball toss distance. The findings suggest that individuals with higher trunk rotational strength not only produce increased racket velocity but also have increased. directional control and hence employ marked contributions by trunk musculature to power as well as accuracy of overhead badminton strokes.

Biomechanically, the trunk functions as a middle connection in the kinetic chain, passing energy. from the lower extremities through the pelvis and torso to the upper limbs and racket. Effective trunk rotation enables athletes to create and transfer angular momentum while ensuring postural stability, important for high-velocity overhead motion. Better trunk rotation enables superior angular velocities, stabilizes the lumbopelvic area with explosive movements, and optimizes energy transfer with proximal-to-distal sequencing. This concept is similar to the kinetic chain theory, stating that proximal segment coordination improves the function. of distal segments, a concept very important for rotational sports such as badminton, baseball, tennis, and cricket.

The notable correlation between the rotational power of the trunk and the accuracy of the forehand smash underscores the functional. significance of muscles in the core, such as the obliques, transverse abdominis, multifidus, and erector spinae, in regulating trunk rotation. Smash accuracy is directly related to racket positioning in smash which is facilitated by powerful core muscles which improve neuromuscular coordination and

minimize energy loss between the segments. Patterns seen in scatter plot confirm this correlation implying that trunk rotation power is involved in both force production as well as movement stabilization which are important for good accuracy while hitting forehand smash.

Many previous studies strongly assist these findings. In a study done by Kibler et al. in 2006 it was highlighted that 50% of energy transfer in complex upper limb movements is because of Core musculature. Another study done by Suda et al. in 2022 shown the direct relation of higher trunk rotational velocity and racket head speed responsible for more powerful smashes.

Nourbakhsh and arab in 2002 explained that reduced trunk coordination significantly reduces limb control and alignment of joint leading to poor performance in overhead sports. Chen et al. (2011) designed 8-week core training program and noted significant enhancement in smash speed and postural stability in adolescent badminton players. Moreover, Shariff et al. (2020) noted the significance of hip and trunk muscle endurance to avoid compensatory patterns and overuse injury with repetitive overhead strokes. Chow et al. (2013) also established that greater trunk rotational torque and muscle endurance improved serve speed, lowered fatigue, and increased energy efficiency in overhead sports. The collective evidence from previous studies aligns with the present results, underscoring the significant role of trunk power in both enhancing performance and preventing injuries.

From a practical point, these insights are valuable for coaches, strength and conditioning professionals and physiotherapists. incorporating trunk – focused exercises such as rotational medicine ball throws, cable rotations, Russian twists, and planks can enhance neuromuscular control and trunk stability, thereby improving the

execution of overhead strokes. The medicine ball toss test, in particular, offers a cost-effective, reliable and easily reproducible way to evaluate trunk strength, making it well suited for both training academies and physiotherapy practice. Strengthening the trunk may also help in maintaining spinal alignment, improving postural stability, and enhancing lumbopelvic control, which together can reduce the risk of common overuse injuries affecting the shoulder, elbow, and lower back in racquet sport athletes exposed to repetitive rotational movements.

Demographic aspects further contextualize the findings. The selected age group (18-25 years) provided a relatively homogenous sample with fewer variations in physiological development. Among the participants, 18 were male (62.1%) and 11 were female (37.9%), offering a balanced gender representation, though potential gender-related differences in trunk power and stroke mechanics were not analyzed. Notably, eight participants (27.6%) were left-handed, which is considerably higher than the global average of approximately 10%, adding an interesting dimension to the cohort characteristics. Even though this study did not conduct subgroup analysis by hand dominance, future studies might investigate the influence of dominant side mechanics, lateral asymmetries, and training adaptations on smash performance and trunk rotation.

Despite the robustness of the findings, several limitations must be acknowledged. The sample size was relatively small ( $n = 29$ ), which restricts the generalizability of the results. Furthermore, the cross-sectional design prevents causal inference. Although a strong association between trunk rotational power and smash performance was observed, it cannot be concluded that enhancing trunk power would directly lead to improved smash performance without confirmation from experimental or longitudinal studies.

Another limitation concerns the testing environment. Smash performance was assessed under standardized and controlled conditions rather than during actual match play, which may limit ecological validity. Moreover, the study did not employ advanced biomechanical tools such as three-dimensional motion capture, surface electromyography, or inertial measurement systems to analysed trunk activation patterns in detail. As a result, the biomechanical insights remain limited.

Future research should therefore consider longitudinal intervention designs to evaluate the effects of structured core-training programs on badminton-specific performance outcomes, while also integrating precise biomechanical analyses to better understand trunk muscle contributions during the smash.

Pre- and post-training measures could assist in establishing causality and capturing functional improvement over time. Incorporating advanced biomechanical tools would allow for detailed evaluation of trunk activation, joint angles, angular momentum, and energy transfer during smashes. Subgroup analyses of gender differences, dominant versus non-dominant side performance, and skill level (amateur versus elite) could provide a more nuanced understanding of trunk contribution to performance. Furthermore, assessing performance under actual match-play situations may enhance the ecological validity of outcomes, measuring the impact of fatigue, opponent control, and decision-making within competitive contexts.

Overall, this research shows a positive correlation between forehand smash performance and trunk rotational power in amateur badminton players. Those with more trunk power had higher stroke force and better accuracy, confirming the initial hypothesis. These results support the significance of core-specific training, functional testing, and biomechanical analysis as essential elements of badminton performance

optimization. In addition, the findings offer practical recommendations for coaches, physiotherapists, and strength-conditioning professionals by emphasizing the two-fold function of trunk training in improving performance and averting injuries. Lastly, the research offers a starting point for future experimental investigations to probe for causality, examine in-depth biomechanical mechanisms, and generalize findings to various playing populations and competitive levels.

## **9. Conclusion**

The purpose of the present study was to find whether if trunk rotational power and accuracy of badminton forehand smash are related or not. After analysing the findings from medicine ball toss test for trunk rotational power and smash accuracy test for forehand smash accuracy, strong correlation was found between them. These results strongly indicate that optimum trunk musculature power is responsible for efficient energy transfer and thereby accuracy of the forehand smash.

The result of the study strongly supports the idea that individuals with higher trunk rotational power have more control over the movement and thus more precision while hitting forehand smash. These findings support the biomechanical fact that the core acts as a primary medium for transfer of kinetic energy in sports that require explosive, overhead movements. The strong correlation found also implies that training aimed to improve trunk musculature power will improve smash hitting performance significantly.

In addition to this, the simplification, cost- effectiveness and reliability of this medicine ball toss test make it a accessible field- based screening and assessment outcome to evaluate power of trunk in the athletic population. It also shows a practical value for sports physiotherapists, strength and conditioning specialists and coaches to improve performance of the athlete and reduce the risk of injuries associated with improper stability of core musculature.

To conclude, this observational study marks as a evidence to support the role of trunk power in performance of the athlete also gives a preliminary support to integrate core strength training for enhancement of performance for amateur badminton players .future studies with large number of sample size, interventional designs, biomechanical

analyses are recommended to establish factors and alongside elaborating on the role of trunk musculature related to various sporting context.

## **Clinical Implications**

- The medicine ball toss test is a simple and practical method for observing trunk rotational power in badminton players.
- Players who possess greater core strength often display improved forehand smash performance
- For physiotherapists, and coaches' measures of trunk power can serve as useful indicators when assessing player performance.
- Assessing trunk strength may also help in identifying athletes who are more likely to develop movement inefficiencies or injuries.
- This observation highlights the importance of including core muscle training as a regular part of conditioning program.

**10.LIMITATIONS AND  
RECOMMENDATIONS FOR FUTURE  
STUDY**

## LIMITATIONS-

- The study included only 29 participants, limiting the generalizability of the findings to a broader population of amateur badminton players.
- The study design was observational, which prevents establishing causal relationships between trunk rotational power and forehand smash performance.
- Smash performance was assessed under standardized test conditions rather than actual match-play scenarios, which may reduce ecological validity.
- Advanced tools such as 3D motion capture, surface EMG, or inertial measurement units were not used to analyse trunk activation patterns, joint kinematics, or energy transfer during smashes.
- Only amateur players were included, so findings may not apply to elite or professional badminton athletes.

## **FUTURE SCOPE**

- Conduct interventional studies to test if structured core training improves trunk rotational power and smash performance.
- Use larger, more diverse samples to enhance generalizability.
- Employ biomechanical tools (3D motion capture, EMG, sensors) for detailed trunk and joint analysis.
- Assess performance in real match-play conditions for ecological validity.
- Explore subgroup differences (gender, dominant vs non-dominant side, lateral asymmetries).
- Study trunk power's role in injury prevention and repetitive strain mitigation.
- Extend research to other rotational sports (tennis, baseball, cricket) for broader applicability,

## **11.Summary**

The present study aimed to investigate the relationship between trunk rotational power and forehand smash performance among amateur badminton players aged 18–25 years. Twenty-nine participants were assessed for trunk rotational power using the medicine ball toss test and forehand smash performance in terms of accuracy and scoring. Statistical analysis using Spearman’s rank correlation revealed a very strong and highly significant positive correlation ( $r = 0.700$ ,  $p < 0.001$ ) between trunk rotational power and smash accuracy, indicating that players with higher trunk rotational strength demonstrated better forehand smash accuracy. These findings highlight the critical role of trunk rotational power in enhancing stroke performance in badminton. The study underscores the importance of incorporating trunk strengthening and rotational power training in badminton-specific conditioning programs to improve skill performance.

## **12.Statement of Funding**

No specific grant or financial support from any funding agency in the public, commercial, or not-for-profit sectors was received for the conduct of this study. The research was entirely self-supported, and therefore funding is not applicable.

### **CONFLICT OF INTEREST**

The authors declare that the present study was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. No external funding, sponsorship, or industry collaboration influenced the design, execution, or reporting of this research.

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## **Annexure**



# 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/2025/154

Date: 09/05/2025

## APPROVAL LETTER APPENDIX - VIII

To,

**CHHANGANI RUSHABH DILIP**  
ABSMARI  
273, PAHAL, BHUBANEWAR-752101

**Protocol Title: Correlation of Trunk Rotational Power with Forehand Smash Accuracy in Amateur Badminton Players**

**Protocol ID.: ABS-IEC-2025-PHY-041**

**Subject:** Approval for the conduct of the above referenced study

Dear **Mr./Ms./Dr Chhangani Rushabh Dilip**

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

MEMBERS
<b>Dr. Smaraki Mohanty</b> Clinician
<b>Dr. Satyajit Mohanty</b> Scientific Member
<b>Mr. Shib Shankar Mohanty</b> Legal Expert
<b>Ms. Annie Hans</b> Social Scientist
<b>Ms. Subhashree Samal</b> Lay Person
<b>Mr. Deepak Ku. Pradhan</b> Scientific Member
IEC-SECRETARIAT
<b>Mr. Gouranga Ku. Padhy</b> <b>Mr. Susant Ku. Raychudamani</b>

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





# ABSMARI ETHICS COMMITTEE

ABHINAV BINDRA SPORTS MEDICINE AND RESEARCH INSTITUTE,  
BHUBANESWAR, ODISHA

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

Prof. (Dr.) E. Venkata Rao  
Chairperson

Mr. Chinmaya Kumar Patra  
Member Secretary

Ref. No. ABSMARI/IEC/2025/154

Date: 09/05/2025

MEMBERS	
<b>Dr. Smaraki Mohanty</b> Clinician	
<b>Dr. Satyajit Mohanty</b> Scientific Member	
<b>Mr. Shib Shankar Mohanty</b> Legal Expert	
<b>Ms. Annie Hans</b> Social Scientist	
<b>Ms. Subhashree Samal</b> Lay Person	
<b>Mr. Deepak Ku. Pradhan</b> Scientific Member	
IEC-SECRETARIAT	
<b>Mr. Gouranga Ku. Padhy</b> <b>Mr. Susant Ku. Raychudamani</b>	

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

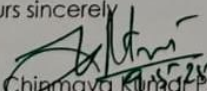
This is to confirm that only members who are independent of the Investigator and the Sponsor of the trial have voted/ provided opinion on the trial.

**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  
Pahal, Bhubaneswar

ABSMARI ETHICS COMMITTEE



2

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**REMEDIC**  
PHYSIOTHERAPY &  
RESEARCH CENTER



*Ashish Agrawal's*  
**SPORTS HEALTH ACADEMY**

Date: 12/08/2025

**Dr. Ashish M. Agrawal** (Physiotherapist)  
B.P.T.H., M.S.P.T., C.O.M.T. (Australia), DRY NEEDLING (Dubai)  
• Ex. Head Physiotherapist, VCA, Nagpur  
• Ex. Head Physiotherapist, CSCS, Raipur  
• Ex. Asst. Prof. Sawangi (M), Wardha

TO WHOMSOEVER IT MAY CONCERN

To

DR. RUSHABH CHHANGANI (PT)

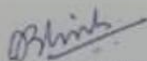
PHYSIOTHERAPIST

We are pleased to inform you that your request has been reviewed and approved. You are hereby granted permission to carry out data collection and associated research activities, subject to the following conditions:

1. All participants must provide informed consent prior to participation.
  2. Data confidentiality and privacy must be strictly maintained.
  3. The research should not disrupt the regular functioning or operations of the club/institution
- We appreciate your interest in conducting ethical and meaningful research and wish you success in your work. Should you require further support or clarification, please feel free to contact us.

For AASHA

Yours Sincerely,

  
Dr. Ashish Agrawal

**REMEDIC**  
PHYSIOTHERAPY & RESEARCH CENTER  
C/o. **Ashish M. Agrawal (PT)**  
B.P.T.H., M.S.P.T., C.O.M.T.  
Reg. No. - 2010/02/PT/000057

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2nd Floor- Vignesh Square,  
Opposite Dinanath High School, Dhantoli, Nagpur, 440012  
Timing : Morning 10.30am - 2.30 pm Evening 4.30 pm to 6.30pm

Dalal Nursing Home, Lane In Front of ICICI Bank,  
Baramji Town, Nagpur - 440 013  
Timing : Evening 7 pm to 8.30pm

## INFORMED CONSENT

Study Title: Correlation of trunk rotational power with forehand smash accuracy in amateur badminton players

Study Number:

Subject's Name: \_\_\_\_\_

Date of Birth / Age: \_\_\_\_\_

Address of the Subject \_\_\_\_\_

Qualification \_\_\_\_\_

Occupation: \_\_\_\_\_

(by subject) -

(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 understand that the Sponsor of the clinical trial, and others working on this. [ ] Sponsor's behalf, 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 I 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.

(iv) 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).

(v) I agree to take part in the above study. [ ]

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

---

Date: \_\_\_\_ / \_\_\_\_ / \_\_\_\_

Signatory's Name: \_\_\_\_\_

Place of the study: \_\_\_\_\_

Signature of the Investigator:

\_\_\_\_\_

Date: \_\_\_\_ / \_\_\_\_ / \_\_\_\_

Study Investigator's Name: \_\_\_\_\_

**CASE REPORT FORM**

NAME:

AGE:

GENDER:

DOMINANCE:

OCCUPATION:

ADDRESS:

CONTACT NUMBER:

OUTCOME MEASURE	
MEDICINE BALL TOSS TEST	
SMASH ACCURACY SCORE	
ACCURACY PERCENTAGE	

### Master chart -

Sl.No.	Age	Dominance	Gender	Medicine Ball Toss Test (m)	Smash Stroke Performance Test	Accuracy Percentage
1	20	right	male	4.87	16	53.33%
2	19	right	female	3.8	18	60.00%
3	22	right	male	4.56	17	56.67%
4	23	right	male	4.71	22	73.33%
5	23	left	female	3.85	18	60.00%
6	24	right	female	3.52	17	56.67%
7	21	right	female	4.11	18	60.00%
8	20	right	male	4.23	17	56.67%
9	24	left	female	3.76	18	60.00%
10	19	right	male	5.04	24	80.00%
11	22	right	male	4.96	20	66.67%
12	23	right	female	4.11	18	60.00%
13	22	left	male	4.74	20	66.67%
14	24	right	female	4.23	16	53.33%
15	18	right	male	5.56	25	83.33%
16	22	right	female	3.56	16	53.33%
17	21	right	female	3.87	17	56.67%
18	20	right	female	4.34	19	63.33%
19	23	left	male	4.63	21	70.00%
20	24	right	male	5.02	18	60.00%
21	22	left	male	4.78	20	66.67%
22	24	right	male	5.24	20	66.67%
23	25	left	male	4.67	19	63.33%
24	18	right	male	5.12	23	76.67%
25	23	left	male	3.87	17	56.67%
26	24	right	male	4.99	20	66.67%
27	18	left	female	3.48	16	53.33%
28	25	right	male	4.97	21	70.00%
29	25	right	male	4	17	56.67%

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