FACTORS DETERMINING BALL RELEASE VELOCITY OF WOMEN PACE BOWLERS IN CRICKET

A SYNOPSIS OF THESIS
SUBMITTED TO THE JADAVPUR UNIVERSITY FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN ARTS

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MAY, 2025

1. INTRODUCTION:

1.1. General Introduction:

Cricket is one of the most passionately followed sports globally, and women's participation in the game is steadily growing. However, there remains a significant gap in research focused on women's cricket, especially in the area of pace bowling. As highlighted by Felton and King (2017), gender-based anatomical and physiological differences necessitate tailored coaching strategies, as training methods effective for men may not yield the same results for women.

Despite extensive studies in men's cricket, research on women pace bowlers is still limited. Ball release velocity, a crucial determinant of pace bowling performance, has only recently gained attention. Studies by Lyons et al. (2023) and Bailey et al. (2023) have emphasized the importance of shoulder angles and run-up velocity in enhancing ball speed in female bowlers. However, these findings are still not comprehensive.

Recognizing this gap, the present researcher undertook the study to explore the key anthropometric, kinematic, and physical fitness factors that influence ball release velocity in women's pace bowling. Understanding these parameters is essential for developing evidence-based coaching and training practices tailored specifically for female cricketers.

1.2. Statement of the Problem:

In the present study, the researcher aimed to identify the key anthropometric, kinematic, and physical fitness factors influencing ball release velocity in women's pace bowling. Accordingly, the thesis is titled **"FACTORS DETERMINING BALL RELEASE VELOCITY OF WOMEN PACE BOWLERS IN CRICKET."**

1.3. Objectives of the Problem:

i. To examine the relationship of selected anthropometric variables namely, upper arm length (acromiale-radiale), forearm length (radiale-stylion radiale), hand length (midstylion-dactylion), arm span, upper leg length (trochanterion-tibiale laterale), lower leg length (tibiale laterale), foot length and standing reach height with ball release velocity of women pace bowlers in cricket.

ii. To explore the relationships of selected kinematic parameters i.e. Run up length, final run-up velocity, bound height, final stride length, ball release height, ball release angle, angle of segmental joints at front foot contact (ankle, knee, hip, shoulder), angle of segmental joints at ball release (ankle, knee, hip, shoulder), flexion of segmental joints from front foot contact to ball release (ankle, knee, hip, shoulder) with ball release velocity of women pace bowlers in cricket.

iii. To analyse the relationships of selected physical fitness parameters like arm strength, back strength, leg strength, upper body power, lower body power, core stability, speed, flexibility with ball release velocity of women pace bowlers in cricket.

1.4. Delimitation:

i. The subjects for this research work were delimited to twelve right-handed women pace bowlers only.

ii. The age range of the subjects was delimited from 18 to 28 years.

iii. The standard of the subjects for this research work was delimited to state level only.

iv. The parameters of this research work were delimited to the selected anthropometric, kinematic and physical fitness parameters only.

v. The data was not collected during competition situations.

1.5. Limitation:

i. Non-availability of sufficient subject from the same level and age group was the main limitation of the study. Only twelve players were found.

ii. The video cameras, used for motion analysis were limited frame quality of 60 fps. Better camera quality with more frame rate capability could result more accurate analysis.

iii. Non-availability of advanced video analysis software was also the limitation of the study. Kinovea 0.9.5 video analysis software was used for analyzing the video.

iv. Weather and non-availability of sophisticated instrument were the limitation of the study.

v. Motivation, arousal and other psychological parameters were not same for all subjects during test.

1.6. Hypothesis:

On the basis of knowledge reflected by the available literature, research findings, experts' opinion of RAC and the scholar's won understanding of the problem it is hypothesized that:

$H_0$1: There would be no significant influence of selected anthropometric parameters namely, upper arm length (acromiale-radiale), forearm length (radiale-stylion radiale), hand length (midstylion-dactylion), arm span, upper leg length (trochanterion-tibiale laterale), lower leg length (tibiale laterale), foot length and standing reach height on ball release velocity in women cricket bowling.

$H_0$2: There would be no significant influence of selected kinematic parameters i.e. Run up length, final run-up velocity, bound height, final stride length, ball release height, ball release angle, angle of segmental joints at front foot contact (ankle, knee, hip, shoulder), angle of segmental joints at ball release (ankle, knee, hip, shoulder), flexion of segmental joints from front foot contact to ball release (ankle, knee, hip, shoulder) on ball release velocity in women cricket bowling.

$H_0$3: There would be no significant influence of selected physical fitness parameters like arm strength, back strength, leg strength, upper body power, lower body power, core stability, speed, flexibility on ball release velocity in women cricket bowling.

2. SUMMARY OF REVIEW:

The reviewed studies collectively examined the relationship between biomechanical, anthropometric, kinematic, and physical fitness factors in cricket pace bowling, emphasizing the key elements that influence ball release velocity and contribute to overall bowling performance. It indicates that ball release velocity in cricket pace bowling is influenced by a combination of anthropometric, kinematic, and physical fitness parameters, though the strength and consistency of these relationships vary.

Anthropometric Parameters

Among anthropometric factors, variables such as upper arm length, forearm length, and arm span have demonstrated moderate positive correlations with ball speed in some studies. For instance, Lyons et al. (2023) reported a correlation of r = 0.61 for arm length, suggesting that longer limb segments may enhance lever mechanics and rotational force. However, other studies like that of Goswami et al. (2016) found negligible correlations, implying that technique and training may modulate these anthropometric advantages. Similarly, leg segment lengths and standing reach height showed inconsistent results, though they may influence stride and release mechanics indirectly.

Kinematic Parameters

Kinematic variables were more strongly and consistently associated with ball release velocity. Notably, final run-up velocity showed a strong positive correlation with ball release speed in several studies (e.g., r = 0.75, Lyons et al., 2023; r = 0.728, Glazier et al., 2000), emphasizing the importance of approach speed. Bound height and stride length varied in their influence. Ball release height and angle also showed some predictive value, with shoulder angle at ball release strongly correlated (r = 0.95, Lyons et al., 2023). Joint angles at both front foot contact (FFC) and ball release (BR) were highlighted as critical, though correlations varied: for example, knee angle at BR showed r = 0.52 (Wormgoor et al., 2010), while hip and shoulder joint movements between FFC and BR reflected meaningful contributions to speed generation (e.g., shoulder flexion r = 0.636, Hanley et al., 2005). Flexion transitions—like knee or hip flexion from FFC to BR—were particularly relevant in studies focused on motion sequencing.

Physical Fitness Parameters

Several physical fitness measures showed moderate to strong correlations with ball release velocity. Core stability (e.g., r = 0.736, Anand et al., 2017), upper body flexibility (e.g., r = 0.726, Sisodia & Bagchi, 2017), and sprinting speed (e.g., r = -0.482 for 30m sprint time, Kiely et al., 2021) were positively associated with faster bowling.

Upper body power, as measured by the medicine ball throw test, and back/leg strength had limited supportive evidence. Arm strength was assessed by Goswami et al (2016), and was reported insignificant but strong positive relation and suggested to contribute to increase ball release velocity.

Overall, the review of related literature supports that kinematic factors, especially final run-up velocity, joint angles, and ball release height, show the strongest and most consistent relationships with ball release velocity. Anthropometric characteristics and physical fitness components, while individually less predictive, contribute significantly when integrated into a comprehensive biomechanical and physiological profile of pace bowlers. In summary, the evidence suggests that while anthropometric traits provide foundational physical advantages, it is the kinematic execution and physical fitness capacity, particularly related to speed, power, and joint movement efficiency, that most strongly determine ball release velocity in pace bowling.

3. METHODOLOGY:

3.1. Selection of Subjects:

Twelve healthy female pace bowlers who have performed in state level tournaments, with no severe previous injury were selected as the subjects for the study. The age of the subjects ranged from 18 to 28 years. They have trained themselves under the guidance of qualified coaches in different academy and all of them must have had the representation in the state level tournament at least once within the last 5 years and they were active participants in the game during the time of data collection for the purpose of study.

3.2. Selection of the Variables:

The following variables were measured to conduct the research-

3.2.1. Demographic Details:

i. Age

ii. Height

iii. Weight

3.2.2. Dependent Variables:

i. Ball release velocity

3.2.3. Independent Variables:

A. Anthropometric parameters:

i. Upper arm length (Acromiale-radiale)

ii. Forearm length (Radiale-stylion radiale)

iii. Hand length (Midstylion-dactylion)

iv. Arm span

v. Upper leg length (Trochanterion-tibiale laterale)

vi. Lower leg length (Tibiale laterale)

vii. Foot length

viii. Standing reach height

B. Kinematic parameters:

i. Run up length

ii. Run-up velocity at pre-delivery stride

iii. Bound height

iv. Final stride length

v. Ball release height

vi. Ball release angle

vii. Ankle joint angle at front foot contact (FFC)

viii. Knee joint angle at front foot contact (FFC)

ix. Hip joint angle at front foot contact (FFC)

x. Shoulder joint angle at front foot contact (FFC)

xi. Ankle joint angle at ball release (BR)

xii. Knee joint angle at ball release (BR)

xiii. Hip joint angle at ball release (BR)

xiv. Shoulder joint angle at ball release (BR)

xv. Ankle plantar flexion from FFC to BR

xvi. Knee flexion from FFC to BR

xvii. Hip flexion from FFC to BR

xviii. Shoulder flexion from FFC to BR

C. Physical Fitness Parameters:

i. Arm strength

ii. Back strength

iii. Leg strength

iv. Upper body power

v. Lower body power

vi. Core stability

vii. Speed

viii. Flexibility

3.3. Procedure for the Administering the Test:

a) Demographic Details:

To measure the age of a group of people, their birthdates, including the year, month, and day, were first collected either from their matriculation certificate or AADHAR card. The height of the subjects was measured by using a stadiometer. A weighing machine was used to measure the weight of the subjects.

b) Anthropometric parameters:

All anthropometric parameters were measured as per the book, "International Standards for Anthropometric Assessment", (ISAK, 2001) and the book, "Practical Measurements for Evaluation in Physical Education" (Johnson & Nelson, 1986).

c) Kinematic parameters:

All the kinematic data were drawn by analyzing and digitizing the video footage of the bowling action, recorded from three different place of right and left sagittal plane.

Recording of Movements:

Three high-speed video cameras (Camera 1: Nikon D7500, Camera 2: Canon 1200D and Camera 3: Canon 1200D) of 60 fps each were used for recording the video of the pace bowling technique. Camera-1 (focusing on the area of delivery stride) and Camera-3 (focusing the run-up) were positioned in right sagittal plane and perpendicular to the pitch. Camera-2 was placed in the left sagittal plane of the pitch in the same way as Camera-1 was placed.

Before making videography of bowling action, the purpose of recording was briefly explained to the subjects. After sufficient warm-up, each subject has performed six (6) successful bowling into the valid area. A reference scale (Height: 1m and Width:

1.5m) was also recorded in the same video putting on the exact line of the movement for the purpose of length calibration at the time of video analysis. A successful bowling was defined as the ball in the legal delivery towards the stump (batsman side) on the pitch.

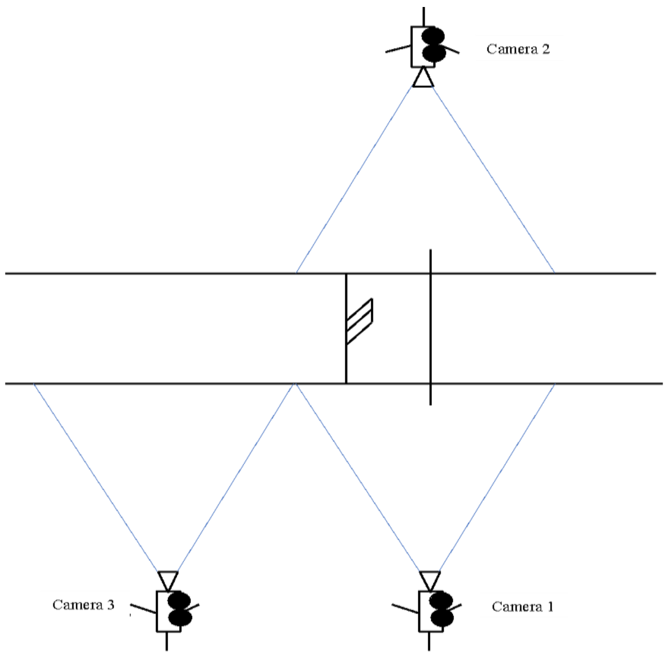

Figure 1: Illustration of Filming Environment

Method of Video Analysis for Kinematic Parameters: After recording the video it was transferred from the cameras to the computer and with the help of the Kinovea (0.9.5) motion analysis software, the pace bowling action of each subject was analyzed for collecting the kinematic data. For measuring all the length parameters, the reference scale (1m x 1.5m) was used, which was recorded in the beginning of the video. For all the velocity parameter, frame rate (60 fps) of the video was used for calculating the time taken for any kind of displacement.

Physical Fitness Parameters:

To measure the selected physical fitness parameters, the subjects were gone through some specific tests as follows:

i.	Arm strength:	Hand grip dynamometer
ii.	Back strength:	Back and leg dynamometer
iii.	Leg strength:	Back and leg dynamometer
iv.	Upper body power:	Overhead medicine ball throw
v.	Lower body power:	Vertical jump test
vi.	Core stability:	Plunk hold test
vii.	Speed:	20m speed test
viii.	Flexibility:	Sit and reach test

3.4. Design of the Study:

Twelve active, state-level female pace bowlers (aged 18–28) from West Bengal were selected using purposive sampling after contacting various coaching camps. Data collection took place at Jadavpur University on 28/03/2024 under RAC supervision. Measurements included demographic, anthropometric, kinematic, and physical fitness parameters. Anthropometric assessments followed ISAK standards. Kinematic data were recorded using three high-speed cameras (60 fps) and analyzed via motion analysis software with length calibration. Each bowler delivered six valid balls. Physical fitness was assessed through standardized tests like handgrip, back and leg strength, vertical jump, medicine ball throw, prone hold, 20m sprint, and sit-and-reach. The procedure is shown in Figure 38.

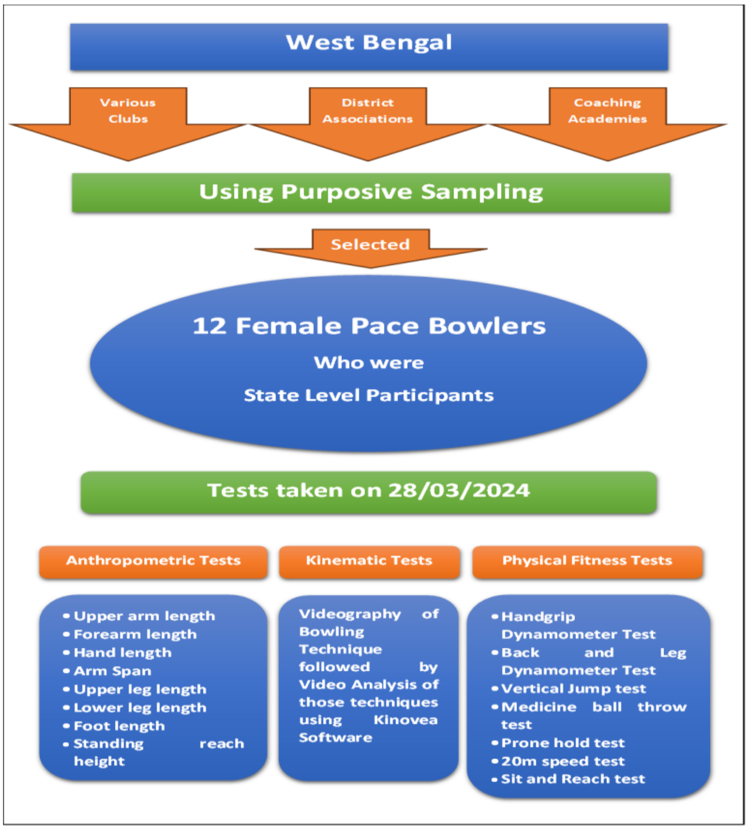

Figure 2: Illustration of Design of the Study

3.5. Statistical Procedure:

Descriptive means, standard deviations, and ranges of all variables were calculated and evaluated. Pearson's product moment correlation and regression analysis were used to analyze relationship among the variables. MS Excel and SPSS statistical software was used for the statistical analysis.

3.6. Level of Significance:

The level of significance was set at 0.05 level of significance for testing the null hypothesis in the study.

4. RESULT AND DISCUSSION:

4.1. Anthropometric Variables

Despite conventional expectations that greater body dimensions (e.g., arm length, height) are positively correlated with higher ball release velocity (BRV), this study found no significant relationship between these anthropometric variables and BRV. This may be attributed to the complex interplay between fitness, strength, and technique. Participants might have had favorable body structures but lacked the physical conditioning or technical skills necessary to translate these into high velocities.

The small sample size (N = 12) may have contributed to these non-significant results, with potential outliers skewing outcomes. Similar findings were reported by Loram et al. (2005) and Wormgoor et al. (2010). Goswami et al. (2016) also found insignificant correlations, with slight negative relations for arm length and slightly positive for hand length.

4.2. Kinematic Variables

Final Run-up Velocity

A significant positive correlation ($r = 0.373$, $p = 0.001$) was found with BRV, and it emerged as a strong predictor in regression analysis. This supports the biomechanical principle of momentum transfer, where higher approach speeds enhance kinetic chain efficiency. Similar trends were observed in Lyons et al. (2023) and Glazier et al. (2000).

Bound Height

A significant negative correlation was found (Best: $r = -0.587$, $p = 0.045$; All: $r = -0.480$, $p = 0.000$), suggesting that excessive vertical movement during the bound disrupts horizontal momentum, lowering BRV. This is supported by Bull et al. (2024).

Ball Release Height

BRH was negatively correlated with BRV (r = -0.283, $p = 0.016$). A lower release point may facilitate better control and energy transfer. Findings align with Kiely et al. (2021) and Thander et al. (2019).

Ball Release Angle

A strong positive correlation was observed (r = 0.712, $p = 0.000$). Optimizing the release angle is crucial for maximizing velocity through effective joint kinematics. This is a novel finding, with no prior correlation studies available for direct comparison.

Knee Joint Angle at FFC

A significant positive correlation (r = 0.365, $p = 0.002$) suggests that larger knee angles at FFC provide a stable base, enhancing kinetic chain function. This supports Lyons et al. (2023), though earlier studies reported insignificant or opposite trends.

Ankle Angle at Ball Release

A strong positive relationship was observed (r = 0.727 best, r = 0.693 all), and ankle angle was a significant predictor in regression. A well-aligned ankle enhances force transmission, supporting biomechanical efficiency. No earlier study provided direct comparisons.

Knee Angle at Ball Release

Significantly correlated with BRV (r = 0.604 best; r = 0.572 all), indicating that greater extension improves BRV. Consistent with Wormgoor et al. (2010).

Hip Angle at Ball Release

A significant positive correlation (r = 0.264, $p = 0.025$) suggests larger hip angles enhance BRV, possibly due to improved torque generation through the pelvis. No prior studies for direct comparison.

Shoulder Angle at Ball Release

A significant negative correlation (r = -0.458, $p = 0.000$) indicates that more flexed shoulders enhance velocity. Although some studies report the opposite, this finding aligns with Hanley et al. (2005).

Ankle Plantar Flexion from FFC to BR

Significant correlations across all metrics ($p < 0.05$) highlight the importance of plantar flexion in force generation. This supports the ground reaction force principle but remains a relatively novel finding.

Knee Flexion from FFC to BR

A significant negative correlation (r = -0.547, $p = 0.000$) suggests less knee flexion is beneficial for BRV, preventing energy absorption that can break the kinetic chain. Findings align with previous studies, including Wormgoor et al. (2008, 2010) and Kiely et al. (2021).

Hip Flexion from FFC to BR

Significant predictor in regression analysis (B = 0.049, p = 0.02), indicating greater flexion improves BRV. Supports biomechanical concepts of torque generation and force alignment, with partial alignment to prior studies.

Shoulder Flexion from FFC to BR

Significant predictor (B = 0.025, p = 0.000), indicating greater shoulder flexion enhances BRV. This supports angular motion theory, with findings in agreement with Hanley et al. (2005).

4.3. Physical Fitness Variables

Arm Strength

Strong positive correlation (r = 0.61, p = 0.035). Greater upper-body strength improves force application and energy transfer during delivery. Consistent with Goswami et al. (2016).

Leg Strength

Significant positive correlation (r = 0.616, p = 0.033). Lower-body power supports effective push-off and momentum generation. No prior studies available for comparison.

Core Stability

Core strength (via prone hold) was significantly correlated (r = 0.577, p = 0.050) with BRV. This supports trunk control and kinetic chain coordination. Aligns with Anand et al. (2017).

Speed (20-m Test)

Significant correlation (r = 0.581, p = 0.048). Faster bowlers generate greater momentum, leading to higher BRV. Findings align with Kiely et al. (2021).

Flexibility

Flexibility was the strongest predictor (r = 0.646, p = 0.023). High flexibility supports better joint range of motion and injury prevention, optimizing bowling mechanics. This variable appears underrepresented in prior research.

5. CONCLUSION:

On the basis of the results and discussions of anthropometric variables, kinematic variables and physical fitness variables, the following conclusions may be drawn:

Anthropometric Variables:

i. The selected anthropometric parameters of women pace bowlers do not influence the ball release velocity significantly.

Kinematic Variables:

i. A higher final run-up velocity contributes to an increase in ball release velocity in women's cricket pace bowling.
ii. A greater ball release angle enhances the ball release velocity in women's cricket pace bowling.
iii. A larger knee joint angle at front foot contact and ball release improves ball release velocity in women's cricket pace bowling.

iv. A greater ankle joint angle at ball release aids in increasing ball release velocity in women's cricket pace bowling.

v. A wider hip joint angle at ball release facilitates the ball release velocity in women's cricket pace bowling.

vi. Increased ankle plantar flexion from front foot contact to ball release leads to a higher ball release velocity in women's cricket pace bowling.

vii. Greater hip flexion from front foot contact to ball release contributes to improved ball release velocity in women's cricket pace bowling.

viii. Increased shoulder flexion from front foot contact to ball release helps in achieving higher ball release velocity in women's cricket pace bowling.

ix. A reduced bound height supports to increase in ball release velocity in women's cricket pace bowling.

x. A lower ball release height enhances ball release velocity in women's cricket pace bowling.

xi. A smaller shoulder joint angle at ball release aids in increasing ball release velocity in women's cricket pace bowling.

xii. Lesser knee flexion from front foot contact to ball release results in higher ball release velocity in women's cricket pace bowling.

Physical Fitness Variables:

i. Greater arm strength of women pace bowlers has positive impact on ball release velocity in women's cricket pace bowling.

ii. Enhanced leg strength contributes to higher ball release velocity in women's cricket pace bowling.

iii. Improved core stability supports an increasement in ball release velocity in women's cricket pace bowling.

iv. Higher running speed of women pace bowlers helps to boost ball release velocity in women's cricket pace bowling.

v. Better flexibility of women pace bowlers positively affects ball release velocity in women's cricket pace bowling.

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