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A Study on the Decoding of the Medium Bowling Technique Using Apple Watch in Real Time Observations.

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Abstract
Background: Scientific approaches help to identify the technical expediency and improves consistency of the bowling performance. High-speed cameras and motion analysis tools capture arm rotational patterns, angular velocity, and sequencing the upper body movements during delivery. Arm movements in Cricket, fast bowling plays a critical role in pitching the ball by means of bulls-eye accuracy, controlled line and length. Real-time analysis of arm rotation in Cricket applies biomechanical methods to assess the bowling arm path, speed, and angles of the bowlers. **The Aim:** The aim of the researchers are to design a suitable real-time procedure to analyse the bowlers' arm rotation mechanics using inertial measurement unit (IMU) mounted in conventional smart watches (Apple watch ultra-2). **Methodology:** To achieve this purpose four male side-on right arm medium bowlers from the Gandhigram Rural Institute (Deemed to be University), Gandhigram were recruited. Methods are designed to determine the following parameters such as Ball Speed, Release Time, Wrist Flexion, Wrist Snap, Peak Pronation, Peak Supination, Pronation of Arm, Supination of Arm, Arm rotation Speed and Height of ball release relating to bowlers' arm rotation mechanics. Bowlers' arm rotation mechanics was synchronized with the test device data (SensorLog) matching with the gyroscope, accelerometer and the quaternion values. Ball speed was measured by using Pocket Radar Gun (Smart Coach). **Results:** Bowlers' linear acceleration of arm movement was observed through tri-axial accelerometer sensor and described in a graphical way. **Conclusion:** The present research concluded that, bowlers had their personalized release, wrist and arm rotational movement pattern. At the same time, ball release time and height of ball release was strongly associated with the bowling speed.
Key words: Cricket, Medium bowling, real-time analysis, arm rotational movement and sensors

Introduction

Cricket is a bat-and-ball game played between two teams of eleven players each on an oval-shaped field featuring a central pitch 22 yards in length. The objective of the game is to accumulate runs while simultaneously restricting and dismissing the opposing team. In the current scenario, Cricket is governed by ICC and conducted in three primary formats: Test matches, One Day Internationals (ODIs), and Twenty20 (T20) matches. Each of these formats differs in terms of duration, bowling, batting and fielding style of play. In Test Cricket, bowlers tend to demonstrate gradual and sustained improvement, focusing on endurance, accuracy, and strategic variation over extended periods of play. In the 50-over ODI format, bowlers show development through a balance of control and adaptability, refining their ability to manage different phases of the game, including power-plays and death overs. In contrast, T20 Cricket emphasizes rapid skill enhancement, where bowlers must quickly improve their variations, precision, and decision-making under high-pressure situations. Overall, the progression of bowling skills varies across formats, with each format shaping performance characteristics differently while contributing to the overall growth and effectiveness of bowlers.

In Cricket, fast bowling represents a highly complex biomechanical activity involving a coordinated sequence of movements from the run-up phase to ball release **(Olivier et al., 2015)**. **As per Lees (2002)**, assessment procedure serves as the backbone of sports biomechanics. It is quintessential to learn how sports skills are conceived and performed. A video prosents the overall structural method to examine each and every twists and turns of the angle to produce force at the time of bowling.

Yoshida, Nishimura and Jokinen (2018), Biomechanics is the field where the movements of a living body are studied from a mathematical and physics perspective for different purposes, such as ergonomy, healthcare, and sports, among others. Small inefficiencies in technique can significantly influence both performance outcomes and injury risk **(Felton et al., 2023).** Naturally, fast bowlers are particularly susceptible to lower back and lower limb injuries due to repetitive high-intensity loading during the bowling action **(Ferdinands et al., 2026).**

The application of 3D motion capture provides an important opportunity to investigate bowling mechanics in greater detail **(Das et al., 2024)**. In recent years, the discipline of sports biomechanics has played a crucial role in enhancing athletic performance while reducing the likelihood of injury through systematic analysis of human movement **(Olivier et al., 2023)**. Advanced motion capture technologies have enabled researchers to transform complex physical actions into measurable data, allowing detailed evaluation of kinematic and kinetic variables. Among these technologies, three-dimensional (3D) motion capture is widely regarded as the most accurate method for analysing movement patterns, as it provides precise measurements of joint angles, velocities, and accelerations **(Ozkaya et al., 2018).** According to **Ceseracciu et al. (2011)** view point, video analysis for biomechanical purposes has been increasing in recent years. Depending on the complexity of the desired model, this type of analysis can be performed manually, by manually selecting the positions of relevant body parts at different video frames, or automatically, by involving image recognition/processing algorithms to perform this procedure in an automated manner.

Fernandez, Susin and Lligadas, (2012, Dingenen et al. (2015) and **Shere, Kim and Hilton (2019)** stated that, biomechanical analysis can be performed by either video and/or kinematic sensors. In video analysis, 3D and 2D are typically found in the literature, as well as depth detection images. **Polak et al., (2016)** discussed that, some of the most used sensors in the literature to represent human kinematics are: electromagnetic, acoustic, and inertial sensors, Kinect platform (RGB, depth sensors, IR, accelerometers, and microphones), as well as mobile applications. **DeFroda, Thigpen and Kriz, (2016)**, while different sensors provide useful information, video analysis is typically preferred by non-specialized customers because the outputs of the models, expressed as angles or coordinates which complement the videos, are easier to understand. A 2022 review by **Ortiz-Padilla et al.** provides a comprehensive overview of video-based biomechanics tools used to analyze techniques, injury mechanisms, and gait abnormalities in athletes. These insights help athletes fine-tune their performance with surgical precision. In fact, **Teferi and Endalew (2020)** note that combining biomechanical performance analysis with traditional coaching bridges the gap between knowledge and physical execution.

Bowling needs the high degree of motor fitness which smoothen the bowlers' approach run, Jump, back foot contact (BFC), counter arm rotation, front foot contact (FFC), arm angular Speed, point of delivery, wrist snap, release angle, dynamics of non-bowling arm, shoulder, trunk and hips. As a human being one cannot describe the science involved in the fast-bowling progression. Among these, dynamics of fast bowling, arm rotations are said to be the key element in coordinating and optimizing bowling sequence. The vision of naked-eye can no longer be a method to capture, understand, review, describe movement frames in arm rotation. One can understand this momentum of bowling with One's own repeated visual motor behaviour rehearsal or replay (VMBR), self-segmental practice and self-motion analysis of one's actions. However, 2D analysis is an extension to review one's bowling actions, in the modern scenario 3D analysis is believed to be a more reliable scientific approach to expose the unbelievable art of momentum which cannot be possible with naked-eye. The most of the momentum, in particular arm rotation, in bowling takes place in a blink of an eye. To comprehend these bowling sequence, 3D analysis is more suitable. 3D analysis is literally known for laboratory atmosphere and it is preferred for advance athletes. Questions related to mechanics of bowling echoed persistently in researchers' mind for months and years. As a researcher, simply pause that questions and discover the perfect time, the perfect way and the perfect real-time procedure to unfold the mechanics and truth involved / behind the Bowling. The investigators were in urge to develop the real-time procedure to assess the bowling skills in field-based conditions for pre-elite Cricket bowlers with the following objectives.

Objectives of the study

1. To design a suitable real-time innovative procedure to analyse the bowlers' arm rotation mechanics using inertial measurement unit (IMU) mounted in conventional smart watches.
2. To detect the Bowlers' linear acceleration of arm movement through tri-axial accelerometer sensor.
3. To find out the interconnection between the bowlers' arm rotation mechanics and bowling speed detected by a device by Doppler principle.

Methods

Methods are designed to determine the following parameters such as Ball Speed, Release Time, Wrist Flexion, Wrist Snap, Peak Pronation, Peak Supination, Pronation of Arm, Supination of Arm, Arm rotation Speed and Height of ball release relating to bowlers' arm rotation mechanics and are discussed below.

Ball Speed

Ball speed was quantified by using a Pocket Radar Gun (Smart Coach) positioned behind the wicket keeper, 11meters distance from the stumps and at 2.25 meters high.

Cricket Ball

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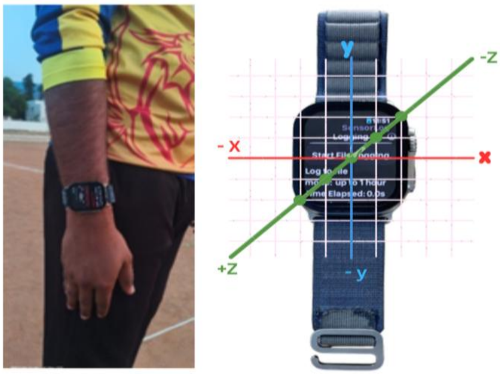
All participants used a white Kookaburra four-piece Cricket ball.

Test Device: Apple Watch (Ultra 2) consisting of a tri-axial accelerometer (measures up to 256 g-forces), gyroscope (high range) and magnetometer was attached to bowlers' bowling arm wrist. Figure-1 illustrated the test device attached to the bowler arm and corresponding X, Y and Z axes of the sensors.

Figure - 1 Test device and its axes



Participants: Four male side-on right arm medium bowlers from the Gandhigram Rural Institute (Deemed to be University), Gandhigram were selected and they were free of injury at the time of testing procedure. Before the commencement of the study, written consent was obtained from all participants. The mean age of the bowlers were recorded as 20.75 years (SD ± 1.5). Bowlers' anthropometric profile was presented in table 1.

Table-1.Bowlers' anthropometric profile

Bowler	Height (cm)	Weight (kg)	BMI	Approach Run Distance (m)	Shoulder Height (cm)	Arm length (cm)
1	175.9	71.35	23.06	18.1	153	65
2	176.9	73.85	18.99	14	151.4	63.5
3	178.2	60.3	18.99	14.2	151	68
4	171.3	83.65	28.51	12.8	145.6	64.5

Design: This study used a purposive sampling design with data collected from a single testing session.

Testing session: After participants have completed their regular warm-up, they were instructed to perform the task. For understanding, participants' performed six practice bowls with verbal suggestions to encourage maximize the bowling speed. Testing procedure was conducted on the outdoor standard Cricket pitch using coir-mat surface. On the test day, each bowler was asked to bowel 12 deliveries and suggested to bowel at a maximum speed, further they were insisted to control their line, length and accuracy of bowling. Among the 12 deliveries, the best top six high speed deliveries were considered for analysis. Thus, a total of 48 deliveries bowled by the bowlers.

Data extraction : The bowlers' arm mechanics event interval (AMEI) time, is considered as the time elapsed between the back foot contact on the pitch and the time of release of the ball by the bowler. In the present study it is observed that, the AMEI is found to vary from bowler to bowler, ranging from 260 – 400 ms. Figure 2 visualize the AMEI time.

Figure- 2 AMEI time - BFC to Ball Release time

The test device is capable of recoding and storing the data corresponding to the entire kinematic events during the AMEI. The bowlers' AMEI, has been manually synchronized with the test device data matching with the gyroscope, accelerometer and the quaternion values. During AMEI, the events occurrence parameters such as release time, wrist snap, pronation, supination, arm rotation speed and height of ball release have been measured for analysis.

The test device, Apple Watch recorded the data and were saved by using the installed application called SensorLog (SensorLog, Germany). SensorLog app have been synchronized with a sampling frequency of 20 Hz. Then the stored data was transmitted as a CSV file to a computer for analysis. The CSV file comprises of number of events identified during the bowling mechanics. The magnitude of stored data of the accelerometer, gyroscope, and quaternion motion along the X, Y, and Z axes were thoroughly examined by following the standard suitable procedure / formula as discussed below. The peak point of the wrist flexion recorded by the gyroscope has been identified and considered as the primary parameter to detect the subsequent event occurrences inferred from the value of gyroscope, accelerometer and quaternion motion.

Wrist loading observation: From the gyroscope X, Y and Z values, the earliest occurrence of peak $|\omega_x|$ value was obtained by noticing the recorded peak value of $|\omega_Z|$ and measured as Wrist Loading.

Arm Rotation Speed: In virtual, arm rotation is the combination of pronation and supination rotational movements' in forearm. In terms of bowling in Cricket, arm rotation speed describes the bowlers' bowling arm rotational movements. From gyroscope values, the researchers understand that, negative and positive values describes the pronation and supination movement of the forearm respectively. In the earlier occurrences of ω_y value was obtained by noticing the recorded peak value of ω_Z and measured as arm rotation speed $|\omega_y|$. From the gyroscope Y values, bowlers' forearm pronation and supination movements was calculated by using the following procedure as suggested by **Boyle, (2016)**i.e.$\Delta_\gamma^{\vartheta} = \int_{t0}^{tf} |\omega_\gamma(t)| dt$.

Wrist flexion and Release Time : In practical aspects of Cricket bowling, the ball release is coincided with the wrist downward pull of the ball to the stumps. From the gyroscope data, ball release was fixed by the wrist flexion which was obtained from the peak value of $|\omega_Z|$.

Release Time: In this connection, from the gyroscope ω_z value, the release time was calculated by using the following steps as suggested by **Ferdinands, Doljin & Fuss, (2021).**

Step 1: Index of maximum

$$i_{release} = argmax\,(|\omega_z|)$$

Step 2: Index to time

$$i_{release} = i_{release} * dt$$

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Height of Ball release: As in sensor Log data, quaternion is generally deals with the orientation of the arm/wrist. From the orientation of the arm, researcher calculated the height of ball release by using equation-1 suggested by **Sutherland (2022)** and **Ferdinands, Broughan, & Round, (2000)**.

$$H_{release} = H_{shoulder} + L.\ V_z \text{ …………………(Eq.1)}$$

$H_{shoulder}$ = Bowler's shoulder height
L = Bowler's arm length (Shoulder to wrist length)
V_z = Quaternion motion Z value = peak $|q_z|$

Over all technique: Bowlers' bowling technique is adjudicated by spotting the time gap between ω_y and ω_z peaks

Accelerometer data : Based on the events occurrences in the accelerometer values, linear movement of the arm was established. Linear movement of the arm describes in X, Y and Z directions. These three axes indicate arm position in space while in delivery. Bowlers arm movements are graphically displayed in analysis part for better understanding.

Results : The collected data were analyzed with suitable statistical technique. Bowlers' bowling ball speed, and relating to bowlers' arm rotation mechanics namely Release Time, Wrist Flexion, Wrist Snap, Peak Pronation, Peak Supination, Pronation of Arm, Supination of Arm, Arm rotation Speed and Height of ball release are discussed below. Descriptive statistics of the above said parameters are below.

TABLE-2. DESCRIPTIVE STATISTICS OF THE BALL SPEED AND ARM ROTATION MECHANICS OF THE FIRST BOWLER

Variables		Unit	Mean ± S. D	Min.	Max.	Correlation between Ball speed and
Bowler	Ball Speed	KMPH	102.5 ±1.76	100	105	1.000
Arm Rotation Mechanics	Release Time	Seconds	0.48 ±0.075	0.4	0.6	-0.905*
	Wrist Flexion	Rad/S	12.58 ±8.25	1.74	23.56	-0.101
	Wrist Snap	Rad/S	10.88 ±9.06	0.481	24.82	-0.146
	Peak Pronation	Rad	6.71 ±8.28	0.921	23.18	-0.041
	Peak Supination	Rad	12.03 ±5.154	1.58	15.10	-0.629
	Pronation of Arm	Rad/S	0.69 ± 0.657	0.061	1.818	-0.264
	Supination of Arm	Rad/S	1.68 ± 0.881	0.150	2.28	-0.452
	Arm rotation Speed	Rad/S	2.37 ± 1.20	0.404	4.10	-0.474
	Height of ball release	Meters	1.74 ± 0.178	1.57	2.06	0.717

$^*r_{(0.05)}4 = 0.811$

Table 2 reveals that, bowler's bowling speed is significantly correlated with their release time. bowling speed is positive association with height of ball release. At the same time remaining parameters wrist flexion, wrist snap, peak pronation, peak supination, pronation of arm, Supination of Arm and Arm rotation Speed are negatively associated with the bowling speed.

TABLE-3. DESCRIPTIVE STATISTICS OF THE BALL SPEED AND ARM ROTATION MECHANICS OF THE SECOND BOWLER

Variables		Mean ± S. D	Min.	Max.	Correlation between Ball speed and
Bowler	Ball Speed	102.00 ±1.67	101.00	105.00	1.000
Arm Rotation Mechanics	Release Time	0.52 ±0.11	0.35	0.60	-0.319
	Wrist Flexion	11.06 ±2.83	7.12	13.61	-0.880*
	Wrist Snap	7.88 ±3.89	2.00	11.28	-0.771
	Peak Pronation	7.03 ±4.15	1.93	11.56	0.118
	Peak Supination	21.84 ±13.85	7.83	38.62	0.314
	Pronation of Arm	1.30 ±1.06	0.10	2.78	0.156
	Supination of Arm	3.03 ±1.62	0.87	5.14	0.736
	Arm rotation Speed	4.33 ±2.45	0.97	7.00	0.554
	Height of ball release	1.64 ±0.11	1.53	1.78	0.849*

$^*r_{(0.05)}4 = 0.811$

Table 3 shows that, bowler's bowling speed is strong positive association with their peak pronation, peak supination, pronation of arm, supination of arm and arm rotation speed and height of release. At the same time, bowler's release time, wrist flexion, wrist snap, are negatively associated with the bowling speed.

TABLE-4. DESCRIPTIVE STATISTICS OF THE BALL SPEED AND ARM ROTATION MECHANICS OF THE THIRD BOWLER

Variables		Mean ± S.D	Min.	Max.	Correlation between Ball speed and
Bowler	Ball Speed	100.00 ±3.29	97.00	100.00	1.000
Arm Rotation Mechanics	Release Time	0.40 ± 0.18	0.25	0.40	-0.726
	Wrist Flexion	18.02 ± 13.01	6.02	18.02	0.627
	Wrist Snap	13.01 ± 7.85	2.12	13.01	0.437
	Peak Pronation	3.35 ± 8.88	-9.62	3.35	-0.585
	Peak Supination	12.42 ± 10.37	2.09	12.42	-0.314
	Pronation of Arm	1.16 ± 0.68	0.33	1.16	0.161
	Supination of Arm	1.63 ± 1.74	0.11	1.63	-0.526
	Arm rotation Speed	2.79 ± 1.70	1.78	2.79	-0.473
	Height of ball release	1.84 ± 0.07	1.73	1.84	-0.161

$^*r_{(0.05)}4 = 0.811$

Table 4 shows that, bowler's bowling speed is positively associated with their wrist flexion, wrist snap and pronation of arm, while the bowler's ball speed is concern, release time, peak pronation, peak supination, supination of arm and arm rotation speed and height of release, are negatively associated.

TABLE-5. DESCRIPTIVE STATISTICS OF THE BALL SPEED AND ARM ROTATION MECHANICS OF THE FOURTH BOWLER

Variables		Mean ± S.D	Min.	Max.	Correlation between Ball speed and
Bowler	Ball Speed	97.00 ±1.90	95.00	100.00	1.000
Arm Rotation Mechanics	Release Time	0.32 ±0.08	0.25	0.45	-0.630
	Wrist Flexion	18.41 ±2.36	15.38	20.76	-0.466
	Wrist Snap	7.06 ±6.88	0.36	17.11	0.168
	Peak Pronation	6.70 ±8.77	-3.96	18.51	0.376
	Peak Supination	19.93 ±8.79	8.62	31.82	-0.270
	Pronation of Arm	0.56 ±0.50	0.11	1.38	0.119
	Supination of Arm	1.61 ±0.45	0.94	2.27	-0.262
	Arm rotation Speed	2.17 ±0.85	1.25	3.26	-0.067
	Height of ball release	1.74 ±0.24	1.47	1.97	0.396

$^*r_{(0.05)}4 = 0.811$

From the Table 5 researcher comprehend that, bowler's bowling speed is positively associated with their wrist snap, peak pronation, pronation of arm and height of release. At the same time, bowler's ball speed is negatively correlated with the release time, wrist flexion, peak supination, supination of arm and arm rotation speed. In addition to the bowlers' ball release time and arm rotational mechanics, bowlers' linear acceleration of the arm movement was displayed in the following figures.

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Figure - 3 First bowler's linear movement patterns and spikes - while the ball is delivered at 105 KMPH Speed

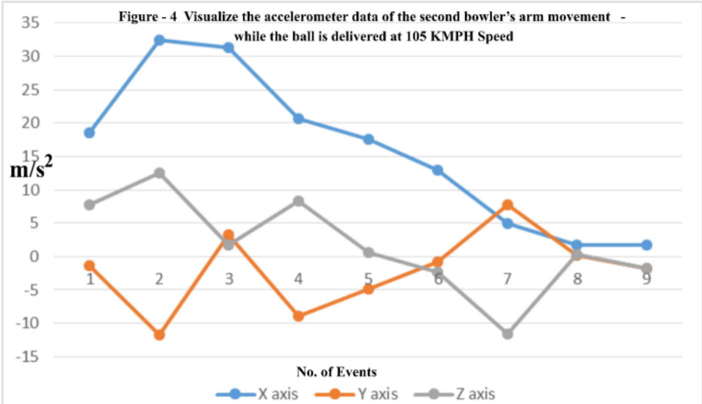

Figure - 4 Visualize the accelerometer data of the second bowler's arm movement - while the ball is delivered at 105 KMPH Speed

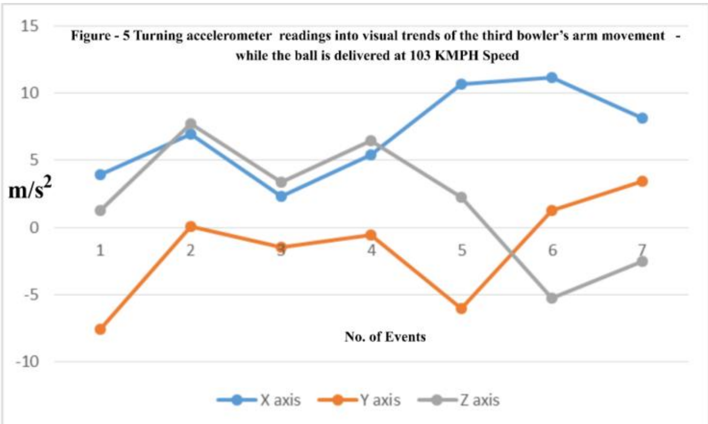

Figure - 5 Turning accelerometer readings into visual trends of the third bowler's arm movement - while the ball is delivered at 103 KMPH Speed

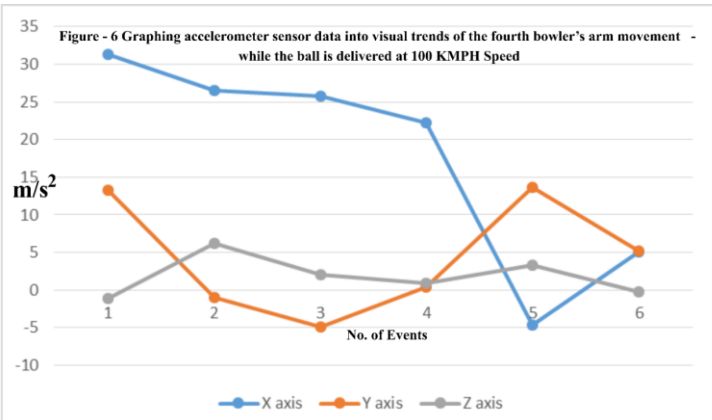

Figure - 6 Graphing accelerometer sensor data into visual trends of the fourth bowler's arm movement - while the ball is delivered at 100 KMPH Speed

Figure 3,4,5 & 6tri-axial accelerometer values indicate the bowlers' arm position in space while in delivery. In which, X values indicates arm moving across the body, Y values indicates arm lift while the bowling action and Z values indicates motion toward the stumps.

Discussion : The primary aim of the present study is to leverage the real-time analysis for arm rotation with bowling speed for a sample of selected bowlers. Form the observations of the authors, it is opined that the fast bowlers are needed to bowel against the great batsman under the placid sunshine in opening and death-overs on a

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seeming pitch, slow pitch and batting pitch. Bowler began his/her smooth run-up, eyes locked on the target, pitched the phase of delivery in leg side or off side with magical out-swing / in-swing /bulls-eye accuracy in line and length deliveries / rolled their fingers and delivered pinpoint slow ball/ fastball Yorker straight up to the stumps / to deliver killing bouncers to restrict the run scoring opportunities. In general, the skilful and perfect delivery depends on the bowlers'anthropometric dimensions such as upper limb length, shoulder width, chest girth, motor fitness parameters and arm rotation pattern. Longer lever provides a greater moment arm, enabling the bowlers to generate higher release velocities with less muscular effort.

The experiment by **Portus et al., 2010** used a radar gun (±0.2 km/h), to measure the ball release speed. In the present study also, the researcher measured the bowlers' ball speed by using a radar gun. Numerous studies have been demonstrated and authenticated the bowling performance by using 3D (**Ozkaya et al., 2018),** Video analysis **(Ceseracciu et al. 2011)** and motion analysis software. Present study describes the real-time procedure to assess the bowling performance. From the analysis of the present research indicates that, selected bowlers had their personalized release, wrist and arm rotational movement pattern it includes Release Time, Wrist Flexion, Wrist Snap, Peak Pronation, Peak Supination, Pronation of Arm, Supination of Arm, Arm rotation Speed and Height of ball release. Previous research of **Van der Vaart, (1994)**, measured the forearm rotation movements by using three-dimensional photo-electronic motion registration system. **Salter et al., 2007** studied the bowling techniques by using two methodologies (between-bowlers and within-bowler) and recommended that within-bowler methodology is better to study the technique relationships. In the present study method also in line with the **Salter et al., 2007** with-in bowler technique analysis.

Skilled bowlers demonstrate an optimal release time and a smooth transfer of angular momentum, whereas an amateur bowler often exhibit a delayed release time and / or an excessive rotation pattern that may disrupt the mechanical flow pattern and may cause increased physical strain on the bowler. This may be the reason for the present research outcomes i.e. personalized release, wrist and arm rotational movement pattern.**Wayne Spratford, et al., (2014)**, explored the linkages between peak outward acceleration and ball release of fast bowler's technique. Figure3,4,5,&6clearly visualized the bowlers' arm movement patterns, spikes or anomalies by using tri-axial accelerometer data.

Conclusion

The present study analysing the fast-bowling highlights by the central role of arm rotation. Bowling performance was not only depends on the rotational mechanics of the bowling arm, and it is a combination of anthropometric measurements, kinematic, and kinetics movements occurred in joints. Arm rotation is generally integrated with the proximal-to-distal sequencing characteristics of the fast-bowling motion. The upper arm initiates the rotational phase of delivery, followed by rapid internal rotation around the shoulder joint and the extension elbow immediately before the ball release. This sequence allows for high angular velocities and effective transfer of energy from the torso to the hand and finally to the ball. From the methodology and analysis of the study the following conclusions have been drawn.

- Decoding of the smart motion tracking system (Apple Watch)is done and is found to be a suitable as a real-time test device in the Cricket bowling analysis procedures under the field-based conditions.
- Sensor fusion methodology is accurate and reliable in the measurement of the critical biomechanical factors contributing to the workload variability during the arm rotation pattern of the bowlers.
- High-g accelerometer provides a comprehensive insight to understand the linear motion of the bowling arm and wrist.
- The bowling speed depends on the ball release time, wrist flexion and height of ball release. It is observed that, the bowling speed is moderately depend upon the Wrist Snap, Peak Pronation, Peak Supination, Pronation of Arm, Supination of Arm and Arm rotation Speed.
- Excessive or inconsistent arm rotation shall alter the entire arm rotation mechanics of the bowling and in turn bowling speed.
- Regular analysis of angular velocity and acceleration during arm rotation becomes vital in interpreting workload data and identifying potential inefficiencies.
- The strength and conditioning staff has the access to capture data in real time, integrating the speed, distance, and angular motion metrics. Besides, the staff may correlate the rotations with overall workload indices and can identify the arm rotation variability, stems from fatigue-induced changes or from intrinsic biomechanical differences arising across match conditions. This in turn enables the staff to design the individualized/tailored conditioning programs for the bowlers to maintain consistent motion patterns, efficient kinetic chain transfer, and for the reduced cumulative joint stresses.
- Future research is in progress to examine the arm rotation variability using the in-field technologies to refine the coaching interventions for optimizing the arm rotational performance of the progressing cricket bowlers.
- Conclusively, the test device innovatively used in the present study, may be successfully utilized in the observation and analysis of 3D motion parameters may evolve in all other sports and games.

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