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BIOMECHANICS OF THE BOWLING DELIVERY IN CRICKET:A CRITICAL ANALYSIS

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Abstract:

The biomechanics of the bowling delivery in cricket has been a subject of extensive research aimed at understanding the key kinematic and kinetic factors that contribute to optimal performance and injury prevention. This abstract presents a critical analysis of the existing literature on the biomechanics of the bowling delivery, highlighting the key findings, limitations, and areas for future research. The bowling delivery in cricket involves a complex sequence of movements that requires the coordination of various body segments. Studies have identified three main bowling techniques: side-on, front-on, and mixed, each characterized by distinct body alignments and orientations towards the batsman. Biomechanical analyses have revealed that these techniques differ in terms of the joint angles, muscle activations, and forces exerted during the delivery stride. One critical aspect of the bowling delivery is the transfer of energy from the lower body to the upper body. Research has shown that an efficient transfer of energy is crucial for generating ball speed and accuracy. Studies have explored the role of different kinematic variables, such as stride length, trunk flexion, and shoulder rotation, in optimizing this energy transfer. Furthermore, the biomechanics of the bowling delivery has been associated with the risk of injury, particularly in fast bowlers. The mixed bowling technique has been identified as having a higher risk of back injuries compared to side-on and front-on techniques. Understanding the biomechanical factors contributing to injury susceptibility can aid in the development of injury prevention strategies and workload management protocols. Despite the advancements in the field, several limitations exist in current biomechanical studies on the bowling delivery. Many studies have focused on laboratory-based analyses using motion capture systems, which may not fully capture the complexities of the game environment. Additionally, limited research has explored the influence of individual variations, such as player skill level, body composition, and fatigue, on bowling biomechanics. To advance the understanding of the biomechanics of the bowling delivery, future research should incorporate on-field analyses, consider individual variations, and explore the impact of fatigue and workload management on performance and injury risk. Furthermore, technological advancements, such as wearable sensors and real-time feedback systems, can provide valuable insights into the biomechanics of bowling in real-game scenarios. In conclusion, a critical analysis of the existing literature on the biomechanics of the bowling delivery highlights the complex nature of this skill and its influence on performance and injury risk. Further research is warranted to address the limitations and explore new avenues, ultimately enhancing the knowledge base and practical applications for optimizing bowling performance and athlete well-being in cricket.

***Index Terms* - Biomechanics, Bowling, Delivery, Kinematic, Kinetic, Cricket.**

1.0. INTRODUCTION

Fast and medium bowling in cricket involves the generation of high ball velocities at the point of release, which requires the application of various forces and torques within the body. Bowlers undergo significant movements and exertion, including twisting, bending, rotation, flexion, and extension, all within a short period of time. Additionally, they must accommodate the ground reaction forces generated during the bowling action.

A bowling delivery in cricket refers to the action performed by a bowler to deliver the ball towards the batsman. It is a crucial aspect of the game where the bowler uses their bowling technique, body movements, and skills to send the ball towards the batsman with the intention of getting them out or restricting their scoring opportunities. The type of delivery can vary, such as fast bowling, spin bowling, or swing bowling, each requiring different techniques and strategies. The bowler aims to generate pace, movement, or spin on the ball to challenge the batsman and contribute to their team's success.

The biomechanics of the delivery in cricket have been the subject of extensive research. Biomechanical studies aim to analyses the movements, forces, and mechanics involved in the bowling action to identify optimal techniques and factors that contribute to performance and efficiency. It is important to note that individual bowlers may have unique styles and variations in their delivery. Therefore, while there are general principles and techniques, each bowler may have their own style and adaptations within the parameters of a successful delivery. By critically analyzing the biomechanics of the delivery in fast bowling, the author aims to contribute to the existing knowledge base, provide insights for coaches and practitioners, and potentially guide future research and development in this area.

1.1. Purpose of the Study

The purpose of the study "Biomechanics of the Bowling Delivery in Cricket: A Critical Analysis" is to critically examine the mechanics of the bowling action in order to improve technique, enhance performance, prevent injuries, support coaching methodologies, and contribute to the scientific understanding of human movement in cricket and beyond.

2.0. NEED OF THE STUDY.

One of the most important aspects of cricket is the bowling delivery, which involves the action of delivering the ball towards the batsman. The bowling delivery in cricket is a critical mechanical analysis that needs to be studied in order to improve performance and prevent injuries. The mechanics of a bowling delivery involve several key elements such as body position, arm action, wrist position, and footwork. Each element plays an important role in determining the accuracy, speed, and spin of the ball. A thorough understanding of these mechanics can help bowlers to develop their skills and achieve consistent results. Moreover, studying the mechanics of bowling delivery can also help prevent injuries. Bowling puts significant stress on various parts of the body including shoulders, back, hips, knees, and ankles. Proper technique can reduce this stress and minimize the risk of injury.

III. RESEARCH METHODOLOGY

To conduct this critical analysis of the biomechanics of bowling delivery in cricket, the following methodology was employed:

3.1 Literature Search:

A systematic literature search was conducted using various electronic databases, including PubMed, Scopus, and Google Scholar. The search terms used were "biomechanics," "bowling delivery," "kinematics," "kinetics," and "cricket." The search aimed to identify relevant studies that focused on the biomechanics of the bowling delivery in cricket.

3.2 Inclusion Criteria:

The inclusion criteria for selecting relevant studies were as follows:

a) Published articles written in English.
b) Studies specifically examining the biomechanics of the bowling delivery in cricket.
c) Studies that provided detailed information on the kinematic and kinetic aspects of the bowling action.
d) Studies involving human participants, such as professional cricketers or skilled bowlers.

3.3 Exclusion Criteria:

The exclusion criteria for study selection were as follows:

a) Articles not written in English.
b) Studies that did not specifically investigate the biomechanics of the bowling delivery in cricket.
c) Studies that did not provide sufficient information on the kinematic and kinetic aspects of the bowling action.
d) Studies conducted on non-human subjects or using simulation models.
e) Studies published outside the predetermined time frame.

3.4 Study Selection Process:

The initial literature search generated a pool of articles related to the topic. Duplicate articles were removed, and the remaining articles underwent a title and abstract screening to assess their relevance. Based on the inclusion and exclusion criteria, a subset of articles was selected for full-text review.

During the full-text review, articles were thoroughly evaluated to ensure they met the specific requirements of the study. Articles that did not provide adequate information on the biomechanics of the bowling delivery or did not focus on the kinematic and kinetic aspects were excluded. The final selection of articles formed the basis for the critical analysis.

3.5 Data Extraction and Analysis:

Data were extracted from the selected articles, including study characteristics, participant details, experimental methods, key findings related to the biomechanics of the bowling delivery, and any limitations mentioned by the authors. The extracted data were analyzed systematically to identify common themes, patterns, and inconsistencies across the studies.

A critical analysis approach was employed to evaluate the quality and reliability of the included studies. Factors such as the study design, sample size, measurement techniques, data analysis methods, and limitations were considered during the analysis to assess the strength of the findings.

3.6 Limitations:

It is important to acknowledge potential limitations of this critical analysis. The search was limited to English-language articles, which may have excluded relevant studies published in other languages. The analysis focused solely on the biomechanics of the bowling delivery and may not have encompassed all aspects influencing bowling performance. Additionally, the predetermined time frame for publication and the study selection criteria may have influenced the representation and generalizability of the findings.

3.7 Ethical Considerations:

Since this critical analysis was based on the review of previously published literature, ethical approval was not required. The ethical considerations associated with the original studies were the responsibility of the respective authors.

The methodology described above provides a systematic approach for conducting the critical analysis of the biomechanics of bowling delivery in cricket. This analysis aims to enhance the understanding of the kinematic and kinetic aspects of the bowling delivery, contribute to sports performance, injury prevention, coaching methodologies, and serve as a basis for further scientific research in cricket biomechanics.

IV. THE FINDINGS OF THE REVIEW

4.1 Phases of a bowling delivery:

A bowling delivery in cricket can be divided into four main phases, as described by McGrath et al. (1996). 1) Run-up to back foot contact, 2) pre-delivery, 3) delivery stride and 4) follow through (McGrath et al., 1996).

4.1.1) Run-up to back foot contact:

The first phase is the run-up to back foot contact, where the bowler slowly builds up speed before leaping into the air to start the pre-delivery stride. The important aspects of the first phase of the bowling delivery, is known as the run-up. During the run-up, the bowler initiates by slowly starting to walk or jog, gradually increasing their speed. The purpose of this phase is to build momentum and generate the necessary speed for an effective delivery. According to Bartlett et al. (1995), the bowler leaps into the air at a specific point, marking the transition into the pre-delivery stride. The length of the run-up can vary and is typically a self-selected distance chosen by the bowler. For fast/medium bowlers, the run-up length tends to range from 10 to 30 meters, as reported by Davis and Blanksby (1976). This range allows bowlers to find a distance that suits their individual style and preferences. Research by Elliott et al. (1986) suggests that bowlers aim to reach the highest possible horizontal velocity about 3 to 4 strides before reaching the bowling crease. This indicates that the bowler aims to maximize their speed just before entering the delivery stride.

The approach velocity, or the speed at which the bowler approaches the bowling crease, has been found to have an impact on the release velocity of the ball, as noted by Stockhill and Bartlett (1993). A higher approach velocity can potentially result in a faster release velocity, contributing to the speed of the delivered ball. These references (Bartlett et al., 1995; Davis & Blanksby, 1976b; Elliott et al., 1986; Stockhill & Bartlett, 1993) provide insights into the run-up phase of the bowling delivery, including the selection of run-up length, the aim for high horizontal velocity, and the influence of approach velocity on release velocity.

4.1.2 The pre-delivery phase:

Indeed, the velocity at back foot impact plays a significant role in influencing the alignment of the hips and shoulders during the delivery stride. According to the study by Burnett et al. (1998), higher velocities at back foot impact have a greater influence on the alignment of the hips and shoulders during the delivery stride in cricket. This suggests that the speed at which the back foot lands during the delivery stride affects the alignment of the bowler's hips and shoulders. This phase concludes when the back foot strikes the ground after completing the leap (Melbourne Cricket Council, 1976; Bartlett et al., 1995). During the pre-delivery stride, specifically while the bowler is in flight, it is observed that the right foot passes in front of the left foot and lands on the ground parallel to the bowling crease, as mentioned by Bartlett et al. (1995).This foot placement is important for maintaining balance, stability, and proper body alignment during the delivery stride.

Indeed, during the pre-delivery stride, there is a notable transition in the shoulder position of the bowler. As stated by Bartlett et al. (1995), that during the bowling action, the shoulders of the fast bowler undergo a positional shift from a regular running position to a position where they are pointing down the pitch and are perpendicular to the bowling crease. This description implies a change in the alignment of the shoulders, indicating that they rotate or turn to face the intended direction of the delivery. This adjustment in shoulder alignment is crucial for achieving optimal bowling technique and directing the ball accurately towards the desired target. It's worth noting that the references provided namely Melbourne Cricket Council (1976) and Bartlett et al. (1995), likely contain more detailed information and insights related to the pre-delivery phase of the bowling delivery.

4.1.3 The delivery stride

The delivery stride, being the third phase of the bowling delivery, is indeed considered the most important phase due to the combination of forces exerted on the body. This phase poses a higher risk for overuse or acute injuries, making it a significant area of research for cricket scientists.

Several studies, including Mason et al. (1989), Foster et al. (1989), and Bartlett et al. (1995), have recognized the importance of investigating the biomechanics and potential injury risks associated with the delivery stride. By understanding the forces acting on the body during this phase, researchers can identify potential injury mechanisms, develop injury prevention strategies, and optimize bowling technique to reduce the risk of injuries.

Overall, research on the biomechanics of the delivery stride is crucial for understanding the factors contributing to performance and injury in fast bowling, and it plays a vital role in optimizing the technique, efficiency, and long-term health of fast bowlers.

The delivery stride in cricket can be further divided into eight important subdivisions that contribute to the overall efficiency and effectiveness of the bowling action namely 1) action classification, 2) back foot strike, 3) front foot strike, 4) stride length and alignment, 5) front knee angle, 6) shoulder and hip orientation, 7) non-bowling arm and trunk movements as well as 8) the ball release (Bartlett et al., 1995). These subdivisions have been identified and studied to gain a comprehensive understanding of the biomechanics involved. By studying these eight subdivisions of the delivery stride in detail, researchers can gain insights into the biomechanical factors that contribute to successful bowling. This knowledge can be utilized to improve coaching techniques, optimize training methods, and enhance overall performance in cricket.

4.1.3. a. Action classification

According to (Portus et al., 2004; Brukner, 2012; Schaefer et al., and 2020; Ferdinands et al., 2010) there are four main fast bowling actions are there: side-on, front-on, mixed, and semi-open. Each technique involves different positioning of the hips, shoulders, and body alignment during the delivery stride.

1. Side-on Technique: In this technique, the bowler's leading hip and shoulder are pointing towards the batsman. This means that the bowler's body is more aligned sideways, with the chest facing towards the side of the pitch rather than directly towards the batsman.

2. Front-on Technique: In contrast to the side-on technique, the front-on approach involves the bowler's hips and shoulders being open, with the angle between the line joining the shoulders and the line between the wickets exceeding 180

degrees at the rear foot strike. This means that the bowler's body is more facing the batsman directly, with the chest pointing towards the batsman.

3. Mixed Technique: The mixed technique combines elements of both side-on and front-on approaches. In this technique, the lower half of the body is positioned in a front-on manner, with the hips and lower body facing the batsman. However, the upper half of the body remains side-on, with the shoulders and chest aligned more towards the side of the pitch.

4. Semi-Open Technique: The semi-open technique is a variation that falls between the front-on and side-on techniques. The upper body position in this technique is between front-on and side-on, suggesting that the chest and shoulders are not fully facing the batsman but are somewhat turned towards the side.

Based on the research studies, it is stated that the mixed bowling technique is most strongly linked to back injuries compared to the side-on and front-on techniques (Portus et al., 2004; Brukner, 2012).

4.1.3. b. The back foot contact:

During the delivery stride in cricket, the back foot contact is a critical moment that marks the transition from the pre-delivery phase to the delivery phase. At this point, the majority of the bowler's weight is placed on the back foot, and various biomechanical movements occur. Trunk flexion, which refers to the forward bending of the upper body, is closely associated with the position of the back foot at contact. When the back foot is placed parallel to the ground, there is a greater degree of lateral flexion in the spine, leading to a more pronounced backward lean compared to bowlers with an open action (Bartlett, & Best, 1998).

This difference in trunk flexion is influenced by the alignment and positioning of the back foot (Bartlett et al., 1995). Studies have shown that the degree of trunk flexion during back foot contact is related to the hyperextension of the back. When the back is restricted in its hyperextension, as observed in some bowlers, the amount of trunk flexion is reduced Penrose et al. (1976). Furthermore, it has been observed that the vertical ground reaction force (vGRF) values at back-foot contact are lower compared to front-foot contact. This suggests that the force exerted on the ground by the back foot is relatively lesser than that exerted by the front foot during the delivery stride.

Understanding the biomechanics of back foot contact is essential for assessing the load distribution and forces acting on the body during bowling. It provides insights into the positioning and movement patterns that can influence performance, injury risk, and overall bowling technique. Coaches and athletes can use this knowledge to optimize training methods, enhance technique, and minimize the potential for injury.

4.1.3. c. Front foot strike:

Front Foot Contact is the final phase of the delivery stride in cricket. It is characterized by the front foot making contact with the ground, and it involves significant ground reaction forces (GRFs) acting on the body (Bartlett, & Best, 1998).

According to Bartlett et al. (1995), the magnitude of the reaction forces at front foot contact during the delivery stride in cricket is influenced by two main factors: approach velocity and front knee angle. These two factors, approach velocity and front knee angle, play a role in determining the magnitude of the reaction forces experienced at front foot contact, which can impact the efficiency and effectiveness of the delivery stride in cricket.

4.1.3. d. Stride Length and Alignment

Stride length is another important aspect of the delivery stride. It refers to the distance between the back foot strike and front foot contact (Bartlett et al., 1995). Stride length is often measured relative to the bowler's standing height, Elliot et al. (1986) and average values ranging from 70-86% for juniors and around 86% for seniors have been reported (Elliot et al., 1986; Elliot et al., 1992; Stockhill, 1994).

The length of a bowler's stride is dependent on their approach velocity (Melbourne Cricket Council, 1997; Elliot et al., 1986). Slower approach speeds result in smaller stride lengths, while faster approach speeds lead to greater stride lengths. Studies have shown different stride lengths based on varying approach velocities. (Elliot, & Foster, 1984)

According to Elliot et al. (1986), the alignment of the back foot, front foot, and the wickets at the batsmen's end is considered crucial in cricket bowling. It is recommended that these three elements should form a straight line. This alignment helps in maintaining balance, stability, and accuracy during the delivery stride. Additionally, Elliot et al. (1986) suggest that the displacements of the front foot relative to the back foot can indicate the type of bowling action being employed. Different bowling actions may exhibit variations in the positioning and displacement of the front foot in relation to the back foot. Analysing these displacements can provide insights into the specific type or style of the bowler's action.

Bartlett et al. (1995) highlight the need for further studies in this area to provide more insights into the direction of front foot placement during the delivery stride. Additional research in this domain could help to better understand the optimal positioning and alignment of the front foot and its impact on the overall bowling performance. Such studies could potentially provide valuable guidelines and recommendations for bowlers and coaches to enhance their technique and effectiveness.

Understanding the biomechanics of front foot contact, stride length, and foot alignment can contribute to the assessment of technique, performance optimization, and injury prevention in cricket bowling.

4.1.3. e. Front Knee Angle

According to Bartlett et al. (1995), front knee actions in bowling can be categorized into three primary types.

The first type is a straight leg action, where the front leg is fully extended or close to being fully extended at the time of ball release. This type of action provides a stable lower body and creates an effective lever, which has the potential to result in higher ball release speed. In the context of a straight leg action, Elliot et al. (1986) suggest that a knee angle greater than 150 degrees is considered indicative of a straight leg action.

The second type is a flexed knee action, where the bowler lands with a flexed knee and fails to fully extend it at any time after front foot contact. In this type of action, the knee angle is less than 150 degrees (Bartlett et al., 1995).

The third type is a slightly bent knee action, where the knee is slightly bent at front foot impact but progressively straightens into a straight leg action at ball release. This action combines the benefits of a straight leg action with the suggested advantage of better force attenuation due to the slightly bent knee at front foot contact (Bartlett et al., 1995).

The choice of front knee action may have implications for bowling performance, stability, and force transmission through the body (Elliot et al., 1986; Bartlett et al., 1995). Understanding the different types of front knee actions can help in analyzing technique, optimizing performance, and addressing potential injury risks in cricket bowling.

4.1.3. f. Shoulder Orientation:

According to Curtin et al. (1974), the orientation of the shoulders during the delivery stride in cricket is influenced by the type of bowling action used by the bowler. The three primary types of bowling actions are side-on, mixed, and front-on. In the pre-delivery stride and as the bowler transitions into the flight phase, the shoulders typically start rotating towards the batsman. This rotation of the shoulders is a characteristic movement in the bowling action and is often observed in various bowling styles. According to Bartlett et al. (1995), during the flight phase of the delivery stride in cricket, the rotation of the bowler's shoulders continues until they align in a straight line with the batsman at 0 degrees. Simultaneously, counter rotation occurs when the bowler's hips begin rotating in the direction of the batsman. At the moment of front foot contact, the majority of the counter-rotation typically takes place. Studies by Elliot et al. (1992) and Stockill & Bartlett (1992) have reported counter-rotation angles ranging from 9 to 13 degrees during this phase. However, some research, such as Foster et al. (1989), has observed counter-rotation angles of up to 40 degrees. The counter-rotation phase of the shoulder is considered significant and has been identified as a potential cause of lumbar spine injuries in fast bowling, as noted by Elliot et al. (1992). Understanding and managing this counter-rotation is crucial to minimize the risk of injuries and optimize the biomechanics of the bowling action.

4.1.3. g. Non-Bowling Arm and Trunk:

According to the Melbourne Cricket Council (1976), the non-bowling arm in cricket serves as an aiming device and also assists in the rotation of the bowling limb. It helps accelerate the bowling arm down and into the side of the body during the delivery stride. For bowlers with a side-on action, Elliot and Foster (1989) recommend positioning the non-bowling arm almost vertically above the horizontal. This positioning allows the bowler to have a clear view of the batsman over the outside and inside of the non-bowling arm. By maintaining this alignment, the bowler can enhance their accuracy and maintain a consistent line of delivery. Indeed, the non-bowling arm is considered crucial in executing an effective bowling action in cricket. According to Bartlett et al. (1995) and Elliot and Foster (1989), the coordination between the front leg and the non-bowling arm is important for initiating the rotation and flexion of the trunk and bowling arm. During the delivery stride, the non-bowling arm and the front leg should move downward simultaneously. This downward movement helps initiate the rotation and flexion of the trunk and bowling arm, which are key components of generating power and speed in the bowling action. As always, it is advisable to consult the latest research, coaching techniques, or seek guidance from cricket experts for the most comprehensive and up-to-date information on this topic.

4.1.3. h. Ball Release and Bowling Arm:

The bowling arm follows a swing pattern similar to sprinting until the back foot strike. The initiation phase of upper arm circumduction occurs between back foot and front foot contact Bartlett et al. (1995). The upper arm should be close to vertical with an angle of around 200 degrees in relation to the trunk, according to Elliott and Foster (1989). Some studies suggest that the arm should be slightly in front of the vertical line with an angle close to 160 degrees (Davis, & Blanksby, 1976). The arm's circumduction between front and back foot contact varies among bowlers and depends on the arm's position at ball release and front foot contact (Bartlett et al., 1995). The arm action contributes to a significant portion of the final ball release speed, ranging from 41% to 50%, with the arm position at front foot contact serving as a parameter for predicting the ball release (Davis, & Blanksby, 1976; Elliott et al., 1986; Tyson 1976). The fingers and wrist, as the most distal segments of the body, also play a crucial role in the final ball release speed Tyson (1976),

4.4 The follow-through phase

The follow-through phase, which is the final phase of a bowling delivery, has historically received less attention compared to other phases. This is primarily because most analyses tend to focus on the delivery stride and the release of the ball, stopping once the ball has been delivered. However, the follow-through phase is still an important aspect of the bowling action and can provide valuable information about the bowler's technique and body mechanics.

During the follow-through, specific movements and positions are desirable to ensure a smooth and efficient completion of the delivery. One aspect of the follow-through is the positioning of the arms. According to Elliott and Foster (1989), the right arm (for a right-handed bowler) should pass the left thigh as closely as possible. This position allows for proper alignment and helps with balance and control after releasing the ball. In addition to the arm position, Elliott et al. (1989) suggest that the bowler should gradually reduce their speed during the follow-through until reaching a stationary position. This gradual deceleration helps to maintain control and stability while minimizing the risk of abrupt stops that could potentially lead to injury.

Although the follow-through phase may not have received as much attention in research, its importance lies in its contribution to the overall mechanics and technique of the bowling action. Analysing and understanding the follow-through can provide insights into the bowler's body control, balance, and ability to complete the delivery smoothly. Further research and analysis of the follow-through phase can enhance our understanding of the biomechanics of fast bowling, potentially leading to improved coaching techniques, injury prevention strategies, and overall performance enhancement for fast bowlers.

5.0 Conclusion:

In conclusion, biomechanics plays an essential role in determining the success or failure of a bowler in delivering their shot accurately and efficiently. Understanding how each step works together in producing an effective bowling delivery can help improve performance by identifying areas that need improvement and correcting them accordingly. By mastering these techniques through practice and repetition, any bowler can become proficient in delivering accurate shots consistently over time leading up to better scores on scoreboard.

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