A Kinematics Analysis of Upper Extrimity Jump Serve Technique Between Professional and Amateur Volleyball Athlete

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ABSTRACT

Background: Volleyball has become a rapidly growing sport worldwide. Mastery of technique is crucial to achieving optimal performance. The jump serve is one of the most important techniques in volleyball, as it is essential for initiating play. **Method:** Therefore, it is necessary to investigate the mastery of this technique through a biomechanical approach. 15 male professional athletes and 15 male amateur athletes participated in this study. The participants performed the jump serve technique, and the data were analyzed using a biomechanical analysis approach. Kinematic parameters measured included the angular velocity of the elbow and shoulder, the maximum angle of the elbow and shoulder, as well as data on ball speed, jump height, and step length. Their mean age were (24.22 ± 2.39) years, height (1.81 ± 0.96) m, weight (78.93 ± 9.49) kg, and volleyball experiences (7.50 ± 3.37) years, respectively. Each participant wore their own sports attire and footwear following a warm-up session. A set of 18 reflective markers was attached to specific body landmarks on each participant. Subsequently, the participants performed jump serves with maximum effort, aiming to land the ball within designated target zones. **Results:** The results of the study show that there is a significant difference in ball speed, with professionals achieving 94 ± 7.4 km/h and amateurs 74 ± 9.7 km/h. Additionally, there were differences in kinematic parameters, specifically the angular velocity of the elbow and shoulder. Professional athletes demonstrated higher angular velocities in both the elbow and shoulder compared to amateurs, with professional elbow extension at 1620 ± 103 rad/s and amateur elbow extension at 1232 ± 88 rad/s. For shoulder flexion, professionals had 1012 ± 87 rad/s, while amateurs had 920 ± 51 rad/s. **Conclusion:** Furthermore, there was a significant difference between professionals and amateurs in maximum elbow flexion angle, but no difference was found in shoulder hyperextension. Based on these findings, it is expected that coaches and athletes will focus on training the kinematic parameters that influence the jump serve technique, as the jump serve is a crucial technique for initiating play in volleyball.

Keywords: Kinematics Analysis; Jump Serve Technique; Professional; Amateur; Volleyball Athlete.

INTRODUCTION

Nowadays, volleyball has gained widespread recognition among the public. Through ongoing reforms and improvements, it has evolved into a global sport. Volleyball is a competitive sport played between two teams separated by a net, where points are scored by successfully delivering the ball into the opposing team's playing area. Effective attacking techniques are essential to secure points in the game. In recent years, volleyball has emerged as one of the most popular sports globally, leading to its rapid development and widespread growth worldwide.

Volleyball in Indonesia has developed rapidly in the last few decades. This development can be seen from the improvement in the quality of play and the achievements of the national team at regional and international levels. A more competitive volleyball league now also provides opportunities for young athletes to showcase their talents and compete at a higher level (1). However, a performance gap persists between professional and amateur athletes, particularly in mastering advanced techniques such as the jump

serve (2). An in-depth analysis of the kinematic parameters involved in the jump serve technique is crucial to optimizing athlete performance and narrowing this gap (3). Comparative studies on this aspect between professional and amateur Indonesian athletes remain limited, highlighting the need for further research to support systematic athlete development (4). The jump serve is a powerful technique in volleyball that involves principles of biomechanics. Factors such as approach speed, shoulder extension angle and centre of gravity height greatly affect ball speed and accuracy. In biomechanics, these body movements during the serve optimise the forces generated to increase the effectiveness of the serve. Advances in motion analysis technology allow for a better understanding of the technique, aiding more efficient and effective training (5). This technique requires precise coordination between vertical jumping and horizontal striking, with highly critical timing to achieve optimal speed and accuracy (6). Recent studies indicate that significant differences between professional and amateur athletes lie in factors such as jump height, arm angle at impact, and ball velocity post-impact (7). A deeper understanding of these differences could serve as a key to designing more effective training programs for amateur Indonesian athletes (8).

Biomechanics as a tool for technique analysis has proven highly effective in optimizing volleyball athletes' performance, particularly in the context of the jump serve (9). The use of motion capture technology and high-speed video analysis enables researchers and coaches to measure kinematic parameters with a high degree of precision (10). Key aspects such as approach speed, take-off angle, body rotation during flight, and arm movement patterns during the striking phase can be analyzed in detail (11). Recent studies reveal that professional athletes exhibit greater consistency in these parameters compared to amateur athletes, reflecting a higher level of technical mastery (12). In the Indonesian context, the application of biomechanical analysis for developing jump serve techniques remains relatively new and has yet to be fully integrated into standard training programs (13). However, preliminary studies have highlighted the significant potential of this approach to enhance the performance of local athletes (14). By comparing the kinematic parameters of movement between professional and amateur Indonesian athletes, coaches and sports scientists can identify specific areas for improvement (15). This, in turn, could lead to the development of more targeted and effective training protocols tailored to the needs and characteristics of Indonesian athletes (16). The broader integration of biomechanical analysis into national athlete development programs holds the potential to accelerate the improvement of jump serve techniques among amateur athletes, thereby narrowing the gap with international standards (17). Therefore, it is necessary to investigate the mastery of this technique through a biomechanical approach.

MATERIALS AND METHODS

Participants. In total, 24 right-handed professional and amateur male volleyball players from national and local volleyball clubs voluntarily participated in this research. Their mean age were (24.22 ± 2.39) years, height (1.81 ± 0.96) m, weight (78.93 ± 9.49) kg, and volleyball experiences (7.50 ± 3.37) years, respectively. The players had prior experience performing jump serves in both practice sessions and Professional or national competitions, enabling them to execute the technique proficiently. For the professional athlete group, participants must hold active player status in an Indonesian Proliga club, Meanwhile, participants in the amateur group must have prior experience competing at the national regional level. None of the participants had sustained any severe neuromuscular or skeletal injuries within the three months preceding data collection. Written informed consent was obtained from all participants before the experiment, and all procedures were approved by the local Ethics Committee.

Data collection techniques. Figure 1 ilustrates the experimental field layout. The experiment took place in a standard volleyball court (18 m in length and 9 m in width) with the net height set at 2.43 m. A 3-camera motion capture system (Sony Alpha) was utilized to record three-dimensional coordinates of reflective markers during the jump serve at a sampling rate of 200 Hz. Ball velocity was determined using a Bushnell Velocity Speed Gun (Bushnell. USA).

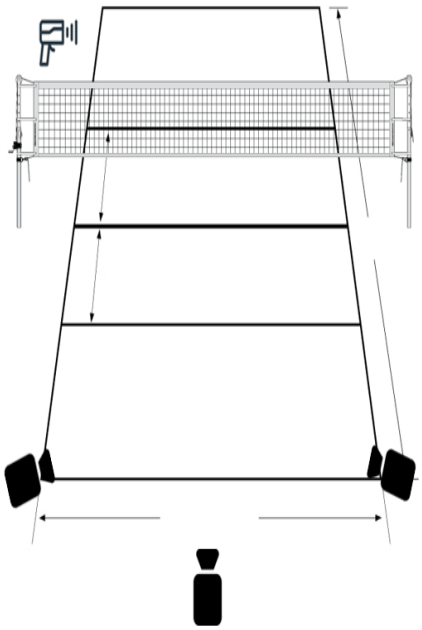

Figure 1. Experimental environment.

Instruments. Each participant wore their own sports attire and footwear following a warm-up session. A set of 18 reflective markers was attached to specific body landmarks on each participant. Subsequently, the participants performed jump serves with maximum effort, aiming to land the ball within designated target zones. Each participant was allowed five attempts to execute the jump serve. During the final step before take-off, participants were instructed to initiate the serve from a specified area. A jump serve was considered successful if the ball crossed the net and landed in the target zone. Participants repeated the jump serve until they completed three successful trials from each serving line. Then observations were made regarding the movement of the upper extremity When performing the jump serve technique, several parameters were observed, namely the angular velocity of elbow extension and shoulders flexion, and maximum angle of shoulder hyperextension and elbow flexion. The jumping height was determine by the maximal vertical position of the center-of-mass minus the standing position and Step length was calculated based on the distance between both feet during a vertical jump.

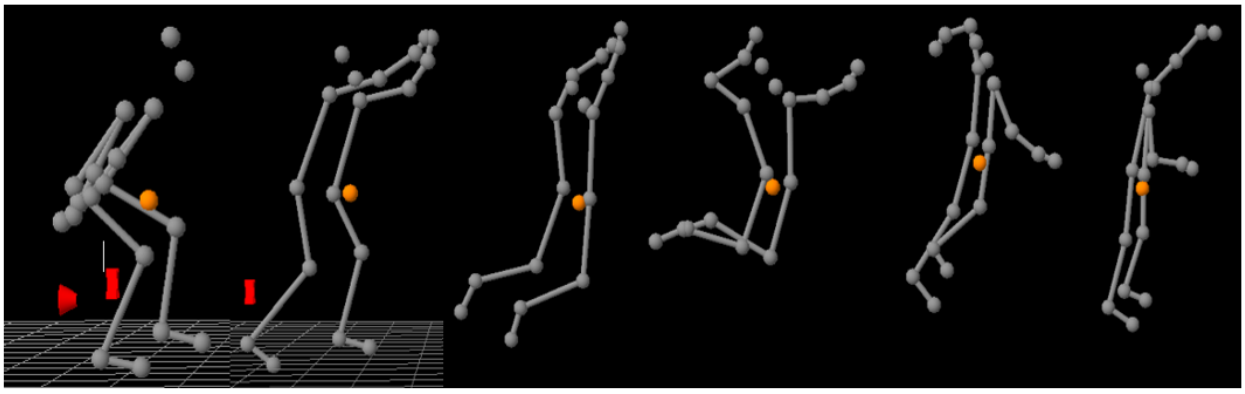

Figure 2. Animation

Ball Velocity: The participants were instructed to warm up before testing, after which they performed five times jump serve technique. After five attempts, the throw with the highest velocity was chosen as the representative indicator. Ball velocity was measured using a radar gun (Speed Gun Bushnell Velocity 101911 range for baseball/softball/tennis: 10‑110 km/h, or up to 90 ft).

Data analysis. Statistical analysis was conducted using the Statistical Package for the Social Sciences (SPSS v. 26.0), and the normality of the sample was assessed using the Shapiro–Wilk test. To evaluate the differences between pre- and post-supplementation results within each group, an independent t-test was applied. A significance level of $p < 0.05$ was considered statistically significant.

RESULTS

First, we compared the ball speed and jump height between professional and amateur athletes. The data revealed that professional athletes exhibited a higher average ball speed in comparison to amateurs, with an average speed of 94 ± 7.4 km/h. However, no significant difference was observed in jump height, with professional athletes recording an average jump height of 0.74 ± 0.07 m and amateur athletes recording 0.67 ± 0.04 m, as shown in Table 1.

Table. 1 Ball Velocity and Jump Height

Variable	Professional	Amateur	Sig
Ball Velocity (km/h)	94 ± 7.4	74 ± 9.7	0.003*
Jump height (m)	0.74 ± 0.07	0.67 ± 0.04	0.114
Step length (m)	1.52 ± 0.13	1.47± 0.21	0.267

Notes : km/h = kilometer/hour m = meter

* Significant difference between professional and amateur values ($p < 0.05$)

Table 2 presents data comparing kinematic variables between professional and amateur athletes during the execution of the jump serve technique. The data indicate significant differences between the two groups in the variables of angular velocity during elbow extension and shoulder flexion. Additionally, a significant difference was observed in the maximum elbow flexion angle, with a significance value of 0.005. However, no significant difference was found in shoulder hyperextension, with a significance value of 0.103.

Table. 2 Kinematic variable

Kinematic Variable	Professional	Amateur	Sig
Angular Velocity (rad/s)			
Elbow extension	1620 ± 103	1232 ± 88	0.002*
Shoulders flexion	1012 ± 87	920 ± 51	0.032*
Maximum Angle (deg)			
Shoulder hyperextension	35 ± 2.3	32 ± 4.6	0.103
Elbow Flexion	105 ± 12	120 ± 9.5	0.005*

Notes : rad/s = radian/second deg = degree

* Significant difference between professional and amateur values ($p < 0.05$)

DISCUSSION

This study aimed to examine the kinematic differences in upper body motion and joint angles during the jump serve technique between professional and amateur players. In volleyball, ball speed particularly during serves, spikes, and smashes heavily depends on the skill level of the players. Professional male volleyball players can achieve exceptionally high serve speeds, particularly with the jump serve. Recent studies confirm that top-level male players often generate serve speeds exceeding 105 km/h. Some elite athletes are capable of serves that reach speeds as high as 130 km/h, depending on their biomechanical efficiency, physical conditioning, and technique optimization. These high serve speeds are heavily

influenced by the player's strength, shoulder mechanics, and explosive power (18; 19). Female professional athletes typically produce slightly lower serve speeds, around 80-100 km/h. In contrast, amateur players generally have lower serve speeds, ranging from 50-70 km/h (Fédération Internationale de Volleyball, 2022). This difference is largely due to less refined techniques and insufficient muscle strength (11). Amateur players often display inefficiencies in striking techniques and body momentum utilization

Vertical jump height is one of the most critical physical abilities in volleyball, particularly for executing spikes, blocks, and serves. The difference in vertical jump height between professional and amateur volleyball players reflects disparities in physical capabilities, technical proficiency, and playing experience. Professional male volleyball players can achieve vertical jump heights ranging from 70 to 100 cm, with some exceeding 100 cm under optimal conditions. This ability is a result of well-developed lower body strength, explosive power, and advanced training techniques. In contrast, amateur male players typically achieve vertical jump heights of 30 to 50 cm, limited by less structured training and physical conditioning (19; 20).

In volleyball, the angle of the arm, shoulder, and wrist during a spike is crucial for the attack's effectiveness. Adjusting these angles affects the speed, direction, and power of the ball, influencing the spike's success. Different arm swing techniques, such as straight and bow-and-arrow, produce varied biomechanical results. Newer techniques can improve ball speed and help prevent injuries (21; 22; 23). An ideal maximum angle in the arm and shoulder allows for optimal activation of key muscles, such as the deltoid, pectoralis major, and triceps brachii. This activation facilitates the maximal transfer of kinetic energy from the body to the ball. Moreover, an accurate hitting angle enables faster arm acceleration, producing a high-velocity ball. Recent studies emphasize that the optimal shoulder angle during the cocking phase in volleyball is influenced by the demands of repetitive overhead movements and their biomechanical implications. Research involving 3D kinematics of elite players demonstrates variations in shoulder joint angles and scapulohumeral rhythm, which are crucial for generating effective spikes while minimizing injury risks. The findings suggest that players develop adaptive movement patterns to maximize performance while maintaining shoulder health, supporting precise assessment for rehabilitation and safe return-to-play protocols (24). In addition, the maximum angle affects the direction and accuracy of the spike. If the angle is too large or too small, the ball's trajectory may deviate, such as landing out of bounds or being intercepted by a block. An optimal angle enables players to control the attack's direction, targeting areas difficult for opponents to reach. Furthermore, the maximum angle contributes to generating topspin. A flexible wrist during the hit imparts topspin to the ball, causing it to drop faster after crossing the net (25).

Angular velocity is a key kinematic factor that significantly influences the quality of volleyball hits, particularly in spike and serve techniques. It refers to the rotational speed of joints, such as the shoulder, elbow, and wrist, during the hitting phase. High angular velocity in the shoulder, elbow, and wrist joints enables a more efficient kinetic energy transfer to the ball. Rapid rotational movement generates linear momentum at the point of contact, ultimately increasing ball speed. High angular velocity optimizes the kinetic chain, allowing energy from the lower body rotation (hips and torso) to be effectively transferred to the arm, hand, and, finally, the ball. Recent research confirms that during volleyball spikes, shoulder angular velocity can reach 2000–3000 degrees per second, contributing to ball speeds of 100–120 km/h. These findings underline the importance of optimizing biomechanics to enhance performance while reducing injury risks. Studies by Rocha et al. (26) and Giatsis et al. (27) highlighted the biomechanical adaptations required for professional volleyball, focusing on arm swing techniques and shoulder dynamics during high-intensity plays. Recent research highlights the importance of controlled angular velocity (CAV) in volleyball spikes for enhancing ball trajectory and accuracy. Elite players achieve peak shoulder angular velocities, which, when coordinated with hip movement, improve ball direction and power. Misaligned or poorly controlled angular velocity often results in inaccurate spikes. Advanced 3D motion capture systems have identified kinematic factors crucial for optimizing performance and preventing injuries (28; 29). However, excessively high angular velocity without adequate muscle stability can increase the risk of injury, particularly to the shoulder (e.g., rotator cuff syndrome). Therefore, developing angular velocity should be balanced with joint stability and muscle strengthening (25).

Therefore, it is essential to consider the kinematic parameters that influence the success and speed of the ball in the jump serve technique. This technique has become increasingly significant in the game, as the jump serve is one of the most aggressive and effective serving techniques in volleyball. It involves a jump before making contact with the ball, allowing the player to generate high ball speed, sharp attack angles, and ball rotation that is difficult for the opponent to anticipate. Recent research confirms that jump serves in volleyball enable male professional athletes to achieve ball speeds up to 130 km/h and female athletes around 100 km/h. These speeds, enabled by biomechanical efficiency and proper training, challenge the receiving team's ability to react and position effectively. Advanced tools like 3D motion capture and radar tracking have been used to optimize these techniques and evaluate their performance metrics (30; 31).

There are other factors that could potentially cause gaps or differences in the execution of the jump serve technique, such as differences in experience, training hours, and physical condition at different levels. In another study, it was explained that there was a positive influence between physical fitness level and technical mastery during competition (32; 33). Furthermore, there is a limitation in the experimental design, where during the service technique, athletes are required to perform a jump serve from a predetermined position. However, in actual gameplay, athletes will serve the ball from different positions according to their preferences. Secondly, the absence of specific data on upper body muscle capabilities in this study means that the researchers cannot yet detail the relationship with shoulder angle speed or ball speed. Lastly, there is a need for a more detailed sample selection related to the specialization in mastering the jump serve technique, as not all athletes are proficient in this technique.

CONCLUSION

This study analyzed the kinematic differences in jump serve techniques between professional and amateur volleyball players. The findings indicate that reducing the elbow flexion angle can help players generate higher ball speeds. During the arm-acceleration phase, the angular velocity of the elbow extension and the angular velocity of the shoulder flexion play a crucial role in maximizing ball speed. These factors highlight significant distinctions between professional and amateur athletes in executing the jump serve. The results of this research are expected to assist coaches and amateur players in improving key kinematic variables that enhance the effectiveness of the jump serve technique.

APPLICABLE REMARK

Kinematic research on jump serve technique between professional and amateur volleyball athletes contributes significantly to an in-depth understanding of the mechanics of the jump serve motion. The findings in this study have broad practical implications, particularly in the development of more measurable and specific training strategies. Coaches and sports administrators can utilize this in-depth analysis to design training programs that focus on improving technique, by precisely identifying differences in movement mechanics between professional and amateur athletes. Methodologically, this study demonstrates the importance of a scientific approach in the analysis of jump serve technique. Through the use of kinematic technology, coaches can provide more accurate feedback to athletes, helping athletes understand and improve each component of the jump serve movement. This is not only applicable to volleyball, but can also be a frame of reference for other sports that require precise motion analysis.

The practical implications of this research are profound, especially in the context of athlete development. By identifying the key movement patterns that differentiate professional and amateur athletes, coaches can design highly specific training interventions. A focus on improving coordination, speed, and precision in jump serve becomes a critical strategy for developing the skills of athletes from beginner to professional level. Furthermore, this study opens up room for further exploration in the future. Recommendations to expand the study to a wider group of athletes, investigate additional factors that influence jump serve quality, and develop more advanced kinematic analysis technologies signify the continued potential in the field of sports research. Such a scientific approach not only improves technical understanding, but also encourages innovation in athlete training and development.

Thus, the applicable remarks of this study emphasize that kinematic analysis is not just a research method, but a strategic tool for understanding, optimizing and developing athletic performance. This study provides

a strong scientific foundation for a measured approach in sports training, particularly in volleyball jump serve technique.

AUTHORS' CONTRIBUTIONS

Study concept and design: Bujang. Acquisition of data: Mia Kusumawati, Mohammad Hamiruce Marhaban, Azlansaufi Ahmad Supian. Analysis and interpretation of data: Iwa Ikhwan Hidayat, Yusuf Hidayat, Ahmad Zaeri Sya'rani. Drafting of the manuscript: Bujang, Mia Kusumawati, Ahmad Zaeri Sya'rani. Critical revision of the manuscript for important intellectual content: Bujang, Mohammad Hamiruce Marhaban, Azlansaufi Ahmad Supian. Statistical analysis: Bujang, Mia Kusumawati, Yusuf Hidayat. Administrative, technical, and material support: Iwa Ikhwan Hidayat,. Study supervision: Bujang, Mohammad Hamiruce Marhaban, Yusuf Hidayat.

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CONFLICT OF INTEREST

There was no conflict of interest in relation to the study carried out.

FINANCIAL DISCLOSURE

This research was supported by Universitas Islam 45 Bekasi. The funding body had no involvement in the design, execution, interpretation, or publication of this research.

ETHICAL CONSIDERATION

Informed consent was obtained from each patient included in the study, and the study protocol conforms to the ethical guidelines of the 1975 Declaration of Helsinki, as reflected in a priori approval by the institution's human research committee.

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ROLE OF THE SPONSOR

The Universitas Islam 45 Bekasi is the agency that provides research funding and has no role in the design and implementation of the research; data collection, management, and analysis; or preparation, review, and approval of the manuscript.

ARTIFICIAL INTELLIGENCE (AI) USE

In this study was not assisted by Artificial Intelligence (AI) and AI-assisted technologies

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