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Original article

Kinematic analysis of volleyball spikes using 2D videography

Análisis cinemático del remate en voleibol, mediante videografía 2D

Análise cinemática de chutes de voleibol usando videografia 2D

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ABSTRACT

Volleyball is a high-intensity and rest-deprived sport that involves different body segments. Therefore, it is essential that the coach properly direct the athlete's physical preparation and maximize their performance. The objective of this study was to analyze the volleyball spiking technique of two athletes from the Itson National Team, in order to identify movement and technique through kinematic indicators. The sampling method was non-probabilistic for convenience; two right-handed university-level volleyball players were

selected; video recordings were made for kinematic analysis using the Kinovea v9.5 program; and variables such as trajectory, leg positioning relative to the body, shoulder rotation, and upper and lower extremity angles were obtained. The results showed deficiencies in phase two, as there was no pronounced dorsal flexion and the knees were flexed 65°, resulting in a lack of force transfer and poor spiking performance. In phase four, the full movement was not performed at the moment of contact with the ball, influencing the speed at which the ball was released. It was considered important to take into account the deficiencies detected in the phases in training, to avoid suffering injuries.

Keywords: analysis, kinematics, phases, spike

RESUMEN

El voleibol es un deporte de alta intensidad y poco descanso, donde se comprometen distintos segmentos del cuerpo, por lo que es fundamental que el entrenador dirija adecuadamente la preparación física del deportista y maximice su rendimiento. El objetivo del estudio fue analizar la técnica del remate del voleibol en dos deportistas del selectivo Itson, para la identificación del movimiento y la técnica mediante indicadores cinemáticos. El tipo de muestreo fue no probabilístico por conveniencia, se seleccionaron dos voleibolistas diestras, categoría universitaria; se hicieron tomas de video, para el análisis cinemático en el programa Kinovea v9.5; y se obtuvieron variables de trayectoria, colocación de las piernas respecto al cuerpo, rotación del hombro, y ángulos de extremidades inferiores y superiores. Los resultados mostraron deficiencia en la fase dos, pues no se tuvo una flexión dorsal pronunciada y las rodillas se flexionaron 65°, lo que provocó la no transferencia de la fuerza y una deficiente realización del remate; en la fase cuatro, al momento del contacto con el balón no se realizó el movimiento completo, lo que influyó en la velocidad a la que salió el balón. Se consideró importante en los entrenamientos tener en consideración las deficiencias detectadas en las fases, para evitar sufrir lesiones.

Palabras clave: análisis, cinemática, fases, remate

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RESUMO

O voleibol é um esporte de alta intensidade, com privação de descanso, que envolve diferentes segmentos corporais. Portanto, é essencial que o treinador oriente adequadamente a preparação física do atleta e maximize seu desempenho. O objetivo deste estudo foi analisar a técnica de ataque no voleibol de dois atletas da Seleção Itson, identificando o movimento e a técnica por meio de indicadores cinemáticos. O método de amostragem foi não probabilístico por conveniência. Foram selecionados dois jogadores de voleibol universitários destros. Gravações em vídeo foram realizadas para análise cinemática utilizando o software Kinovea v9.5. As variáveis coletadas foram: trajetória, posição da perna em relação ao corpo, rotação do ombro e ângulos dos membros inferiores e superiores. Os resultados mostraram deficiências na fase dois, pois não houve dorsiflexão acentuada e os joelhos estavam flexionados a 65°, resultando em falta de transferência de força e baixo desempenho no ataque. Na fase quatro, o movimento completo não foi realizado no momento do contato com a bola, o que influenciou a velocidade de lançamento da bola. Considerou-se importante levar em consideração as deficiências detectadas durante as fases de treinamento para evitar lesões.

Palavras-chave: análise, cinemática, fases, finalização

INTRODUCTION

Volleyball is an exciting sport and due to the tension of the fight that takes place in it, it has stood out since its emergence as a sporting spectacle of great beauty and fast and combined play, given the manifestation of technical-tactical actions that emphasize the leading role of preparation in training (Arronte & Ferro , 2021). It is practiced by young people who try to achieve maximum sporting performance and it is essential to travel a fairly long path of technical and tactical preparation that begins from the player's first steps.

Bernal, Veas & Velásquez (2024) mention that it is a high-speed, explosive, and strength-based sport. Among the different actions that take place throughout the game are mainly changes of direction and jumps in its different fundamentals (attack, block, serve), encompassed in a high-intensity activity with little rest.

The attack or spike, due to the complexity of its technique and the physical demands on the athlete, needs to go hand in hand with biomechanics; García & Hernández (2023) mention that the spike is the most aggressive technique in volleyball and is executed with high frequency during the game, and professional players can repeat it up to 40,000 times throughout a year.

For Song , Wang & Zheng (2023), in volleyball it is impossible to prevent all joints from participating and shoulder injuries are the most common. Although shoulder overuse injuries do not mean the immediate absence of the player from the field, they tend to keep them away from the competition for between four and six weeks, making it the injury that causes the most absences (García & Hernández, 2023).

Shicay & Moscoso (2021) observed seven volleyball players and applied a biomechanical analysis of the angular variation parameters in the elbow, shoulder and knee; hand speed at the moment of impact with the ball and jump height, the results show an average in the brake step subphase of 0.9 m; in the shoulder angle in extension an average of 55.6°, in the same phase and an average of 51.8 cm in height, in the jump phase that can be improved.

The previous study demonstrates that the use of images, videos and execution examples are important for learning the technique of the spike as a long process, constantly evaluated, in order to avoid errors in its execution, and although each athlete has his own style it is necessary to guide him by characterizing the different phases and subphases .

In his research, Shicay (2018) studies 10 female volleyball athletes from the La Asunción Educational Unit, between the ages of 10 and 12, through a biomechanical study and the implementation of improvements to the technique in question, in order to achieve better gestures and sports performance. The results indicate that the values of the approach run

vary significantly, from a lowest value of 1.52 m/s to the highest of 3.18 m/s, because many athletes do not perform the attack technique correctly, they only jump, others do perform the three steps and acquire greater speed. When comparing the average value of 2.4 m/s with the value of the ideal technique 3.2 m/s, it is concluded that it is necessary to improve this action and increase the speed to have a greater range in the jump.

In Montalvo's study (2021), 10 players from the UAH university volleyball team participated. The performance of the vertical jump spike is analyzed simultaneously, using two devices: Vert and Optojump, while the speed of the ball in the spike is measured by means of the Motus QB and the radar.

In both tests, participants make three attempts, taking into account the best result that demonstrates a correlation between both devices for the vertical jump (r=0.886, p=0.001), while the speed of the ball shows no statistical correlation between both devices; in this way, the Vert device seems valid to manage the training load, although it is not recommended when precision in the measurements is required, and the main limitation is that it is carried out on 10 volleyball players, so it is necessary to repeat it with a larger population and thus contrast the validity of the Motus QB device, and a device technologically more advanced than the radar.

Garrido et al. (2017) analyzed three experienced players from different Super League and National League teams using 38 kinematic parameters, including: inter-event times, center of mass position, speed, and height of the shot. Parameters such as flight time, vertical impulse speed, ball release, and range of motion in the executing arm were described, and a protocol and report template were defined as a tool for personalized training based on the observed deficiencies, to prevent possible medium- to long-term injuries.

Because spikers acquire new and different spike techniques in volleyball, various injuries occur, especially in the upper body, which risks their health and participation in important sporting events, in addition to the fact that the spike is one of the factors that determines an attack and significantly affects the results of the game (Suhadi , et al., 2023).

For this reason, the objective is to analyze the volleyball spiking technique of two athletes from the Itson team to identify movement and technique using kinematic indicators.

MATERIALS AND METHOD

The research conducted was a non-experimental, cross-sectional, descriptive study using non-probability convenience sampling. Two volleyball players from the Technological Institute of Sonora, with nine years of experience and no discomfort or injury, were selected for the project.

A documentary review was carried out where the technique of the gesture was investigated, according to García & Hernández (2023); Guzmán et al. (2022); Shicay (2018); Thibodeaux (2023) and a checklist was prepared, the movement was divided into five phases where the execution of the technical gesture was explained and a validation of the checklist was carried out by volleyball experts, based on their experience.

The filming protocol was followed, which included tests for terrain recognition, camera placement, lighting, and general ambiance, in addition to agreeing with Guzmán et al. (2022) on some considerations before recording, such as perspective, distance, tripod use, and spatial calibration. For video recording, the cameras were located on the right side in the three-meter zone (Figure 1).

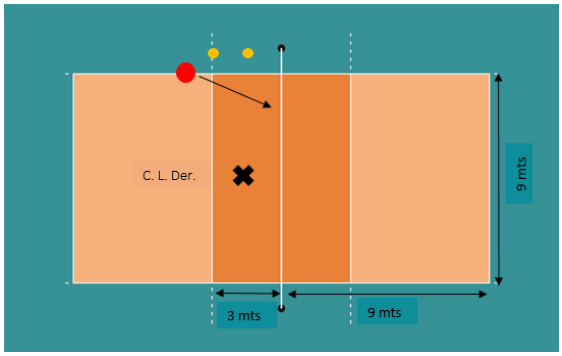

Figure 1. *Camera mounting*

The subjects attended in comfortable clothing, where the anatomical points to be analyzed were marked with passive markers, in accordance with what was indicated by Acero (2013) for a better appreciation on video. Three shots were taken of the right side of each volleyball player (figure 2).

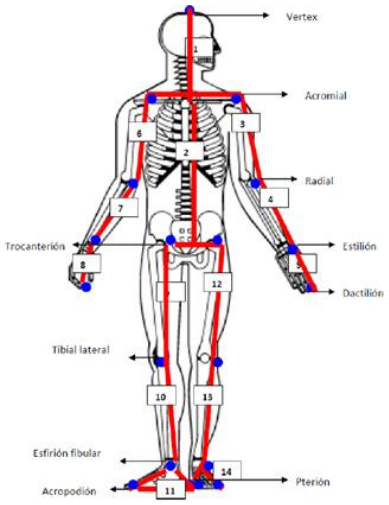

Figure 2. *International scheme for body marking, 14-segment body marking system SC-14.*

The video was taken with a 60 frames per second (fps) Phone XR cell phone and analyzed in two dimensions (2D) using the Kinovea v9.5 program, where the right-side frames of each phase were obtained, and subsequently, the kinematic variables of the trajectory of the segments, the placement of the legs relative to the body, shoulder rotation, and angles of the lower and upper extremities; finally, the volleyball players' spiking technique was compared with the checklist technique.

The entire methodology and filming protocol were compared with Pons et al. (2023) who used the kinovea software in pitching techniques in baseball and with López, Tolano and Toledo (2024) , who found similarities throughout the filming process.

RESULTS AND DISCUSSION

Once the data processing was carried out using the Kinovea v9.5 software (Figure 3) and the technical gesture checklist, the following results were presented:

Figure 3. *Example of kinematic analysis in Kinovea v9.5 subject 1*

In the first phase, the approach run, it was observed that both subjects performed the technique correctly, based on the checklist that was created, with a duration of 0.85 seconds for subject one and 1.42 seconds for subject two. Garrido et al. (2017) reported the kinematic results obtained by the subjects, with a duration of 1.34, 1.25, and 1.77 seconds, respectively.

Montalvo (2021) mentioned that a good speed in the approach run to the spike provided greater explosive strength, therefore, a greater jump height for the next phase, in addition to the angular speed in the legs and the swing of the arms influencing the jump height.

In phase two: jump or beat, it was observed that subject one performed the technique correctly, as he flexed his knees to 42°, made the internal rotation of the left foot, with an explosive vertical jump, once in the air he had a pronounced dorsal flexion and his knees flexed to 89°, with a duration of .38 seconds; subject two had a duration of .48 seconds, in Garrido et al, (2017) the subjects had an average duration of .38 seconds.

At the time of making the vertical jump, subject two, already in the air, did not perform a pronounced dorsal flexion and the knees were flexed at 65°, he did not comply with the knee flexion to approximately 90°, this caused the force not to be transferred nor an effective spike. Although García et al. (2019) considered that the angle of the spine did not influence the finishing technique.

Montalvo (2021) mentioned that the higher the jump during the shot, the greater the effective field size and the shorter the shot trajectory at high speed, in turn, the greater the probability of overcoming the block.

In phase three, hitting preparation, the subjects performed the correct technique, with subject one lasting 0.32 seconds and subject two lasting 0.20 seconds. In contrast, in Garrido et al. (2017), the subjects averaged 0.30 seconds in this phase. The elbow flexion behind the head should have been approximately 90°, so they did comply with that requirement.

García et al. (2019) mentioned that the angle of the elbow considerably influenced the execution of the spike and generated greater force when hitting, and if the technique was not performed correctly, both in the external and internal rotation of the shoulder, there could be injury (Montalvo, 2021), shoulder pain caused by pinching, rotator cuff tendinopathy, glenohumeral instability or suprascapular neuropathy, and the most common rotator cuff.

In phase four: hitting, both subjects made technical errors that could have affected the efficiency of their technique and strike. Subject one's arm, which made contact with the ball, didn't fully lower, affecting the ball's speed; subject two's knees weren't bent, so his attack wasn't effectively executed. This error came from the hitting phase.

Both subjects in phase five landed on only one foot, which could have led to injuries. Montalvo (2021) noted that acute ankle or knee injuries were the most common in volleyball, the most notable being patellar tendinopathy or jumper's knee, caused by the spiker's large number of jumps, both in training and matches. The entire analysis above is represented in Table 1.

Table 1. *Summary of the kinematic analysis of the spike*

Phases	Complies	Does not comply	Observations
Phase 1	1.2		
Phase 2	1	2	- Knee flexion to approximately 90 degrees. - pronounced dorsal flexion.
Phase 3	1.2		
Phase 4		1.2	-Lower the dominant arm (right) to the side of your body. -Legs slightly bent .
Phase 5		1.2	-Land with both feet and the left foot is slightly in front of the right foot.

These deficiencies in the phases of the gesture coincided with Meneses (2023), who found that knee trauma in volleyball players occurred in single-leg landings after horizontal and lateral jumps against movement. The hip presented abduction more than 45° of the lower limb that did not support the ground before and during landing, while support on the ground was made with the forefoot and ankle with plantar flexion. It was recommended to apply strategies that would reduce the risk of traumatic knee injury that involved rapid reactions to changes in kinematics during landing.

CONCLUSIONS

When starting a volleyball career at an early age, it is advisable to consider the technique of the different movements, starting with the study of the spike with high-speed movements and explosive force, not empirically, but with technology, to achieve a better appreciation of the gesture, close to the ideal model, through a training process, with the goal of automating it.

Each of the subjects analyzed and the coach took into consideration the errors of the kinematic indicators of each phase (approach run, jump, preparation for hitting, hitting and landing) detected, such as knee flexion, location of the body segments per phase, and

distances between the body segments, since the spike was the technical gesture most exposed to injury, as it compromises the different structures of the joint to twisting, stretching at high speed and at acute angles, in addition to being repetitive up to 250 jumps per game, with significant mechanical overloads in the upper body in the elbow and shoulder joints; and in the lower body, in the knees and ankles.

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