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A Motion Analysis of Volleyball Open Spike: Kinematics and Performance

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Abstract The purpose of this study was to analyze the open spike motion to identify the performance of Semarang Elite Athletes. The open spike technique in volleyball is indispensable as an attacking strategy because it has a high potential to score. The type of research used is analytical research with a research method in the form of One Short Case Design. The population in this study consisted of 11 PORPROV 2022 athletes and was taken using total sampling. This research was carried out at the PBVSI (Indonesian Volleyball Federation) of Semarang City and each sample had signed an informed consent as evidence of approval for the research carried out. The data in this study were obtained from video recording analysis when the sample did an open spike by using Dartfish version 8.0. The results showed that the average time value achieved by volleyball athletes in Semarang was 1.01 seconds and the average impact was 0.57 seconds. This shows that the spike done by the athlete is quite effective. This study has limitations because it only measures kinematic data, so it is hoped that further research can be deepened by measuring kinetic data such as arm strength and leg muscle explosive power on the results of the open spike carried out.

Keywords Motion Analysis, Open Spike, Volleyball

1. Introduction

The volleyball game, also known as the big ball game, is played in teams of six players each [8]. Volleyball is a sport that is known by all levels of society, this is due to the large number of volleyball matches held both at national and international levels [2]. In February 2020, the Indonesian men's national volleyball team was ranked 70th in the FIVB World Ranking. Volleyball skills for athletes must be developed to improve the performance of Indonesian athletes. According to Palao et al. [21], an athlete's ability to compete at a high level influences the skills displayed. This demonstrates that the higher the level of an athlete on a competing team, the higher the level of play in that match. When an athlete masters' basic techniques well, it reduces technical errors, which are unquestionably detrimental to a team during a match.

Sujarwo [38] argues volleyball has several basic techniques that must be mastered by every player consisting of: serving, passing, setting, hitting, blocking, and digging. Putri [27] points out that volleyball is an intermittent sport comprised of seven basic game phases (serve, pass, set, spike, attack coverage, block, and defense). Some of these fundamental techniques indicate that victory in volleyball can be achieved by scoring as many points as possible. This is accomplished by turning off the ball in the opponent's area, preventing the opponent from receiving and returning the ball because it is too fast;

this technique is commonly referred to as a spike. When carrying out attacks, players tend to be happier. This is because players enjoy the euphoria that comes with floating over the net and hitting the ball into the opposing zone [7]. This is consistent with the opinion of Priambodo et al., [24], who stated that the spike is one of the most important attack weapons in volleyball. Attacking techniques, commonly referred to as spikes. Running, jumping, and floating are the three movements required to carry out an attack. Spike techniques in volleyball are then classified as Open Spike, Semi Spike, Quick Spike, and Back Attack Spike [5]. The spike movement is a very dangerous weapon and is very useful in volleyball games to make it difficult for opponents to anticipate the movement of the ball. This is in accordance with the purpose of carrying out an attack that is very useful for turning off opponents and getting points in the game. There are three methods of doing spikes including hard-driven spikes, off-speed spikes, and deep tip. One of the spike movements that are quite difficult to do is the open spike. This is because the movements are complicated, so long-term practice is needed. Open spike volleyball has several phases that must be considered: approach phase, arm cocking phase, acceleration phase, and follow through phase [36]. According to Santoso & Qiram [34], open spike is done when the position of the ball soars high enough and the ball is calm. Open spike movements require a lot of energy and can make players experience fatigue quickly. Therefore, players need to pay attention to their respective physical conditions because this can affect the open spike movement [30]. Approaching, jumping, hitting, and landing are all factors that can influence the open spike movement. As a result, in volleyball games, attacking movements predominate over defensive movements.

According to Irawan et al., [13], Irawan & Long-ren [15] and Irawan, Nomi, et al., [16], Motion analysis is a technique for improving performance by evaluating a movement. According to the research results on volleyball athletes in Semarang City, 80 % of athletes appear less effective when performing open spike movements. This is because athletes who do not understand the open spike technique properly and correctly need to learn more to improve their performance immediately. Athletes are expected to be able to practice the technique properly and correctly to achieve success in performing the open spike movement. According to research conducted by Putra et al., [26], the spiker's distance from the net was 3.47 m in the early stages of the open spike technique. A three-step approach can be used to maximize the jumping phase. The arm swing angle is 87 degrees, and the leg angle is 149 degrees. The elbow angle formed during the preparation phase is 80 degrees, and the jump height is 53 cm, with two legs used during the landing phase.

From the result of observations and looking at previous studies conducted on volleyball athletes in Semarang City, it is known that athletes are still ineffective, so the throws made are not appropriate. Athletes also still don't understand the open spike technique well. So an analysis of open spike motion is needed to help increase the effectiveness of the open spike movement.

The purpose of this study is to examine the kinematic data analysis of open spike motion of PORPROV volleyball athletes in Semarang City. This study's kinematic data included several indicators, including time, speed, and body segment angles. The goal of this study was to examine the motion of open spike volleyball to identify the performance of PORPROV volleyball athletes in Semarang City. It is hoped that this research would eventually become one of the evaluation materials for athletes and coaches related to improving athlete performance when performing open spikes, and to assisting athletes in achieving maximum performance.

2. Materials and Methods

Analytical research was conducted by using One Short Case Design research method. The data in this study are kinematics data derived from an analysis of Open Spike Volleyball motion through video documentation. Dartfish software was used by researchers to analyze the Open Spike motion (GEAR software version 8 BV, Helmond). A total sampling of 11 male volleyball athletes from Semarang City who are preparing for PORPROV in 2022 were the samples in this study. Each sample has signed an informed consent form and has agreed to participate in all stages of the research until the end. This study has also received Ethical Approval from the Health Research Ethics Commission of Universitas Negeri Semarang.

The instrument used is the Dartfish version 8 application, accompanied by complete equipment in the form of a Canon EOS 750D digital camera, camera tripod, stationery, and cone. The analytical procedures of this research are: 1) inserting video files using a card reader into a laptop, 2) videos being analyzed using Dartfish software version 8 to be slowed down and divided into several phases in motion, 3) the data is then processed using excel to determine the mean; standard deviation; minimum value; and maximum value. This Open Spike motion analysis focuses on the speed of the stroke, the time, the height of the jump, the angle of flexion of the legs, the angle of extension of the trunk of the body, the angle of rotation of the arm, and the angle of flexion of the elbow which consists of the preparation phase, the jumping phase, the impact phase, and the landing phase. The research instrument has been approved and validated by experts.

3. Results and Discussion

3.1. Results

The results of this study are centered on kinematic data

pertaining to the analysis of Open Spike motion in volleyball. Speed, distance, time, and body segment angle are among the indicators discussed in the data. Table 1 shows a description of the research sample used in the analysis of open spike movements.

Table 1. Personal Data of Samples

n = 11	Mean ± SD	Minimum	Maximum
Age (year)	18,9 ± 2,662	12	22
Height (Meter)	1,73 ± 0,063	1,618	1,815
Weight (Kilogram)	68 ± 8,852	49	80
BMI (Kg/m^2)	23 ± 2,386	18	26

The research data consisted of 11 samples from volleyball athletes in Semarang City who were willing to participate in the research until it was completed, as evidenced by signing informed consent and agreeing to be a study sample. According to the data, the average respondent is 19 years old, with a minimum of 12 years and a maximum of 22 years. The average height is 1.73 meters and weight are 69 kilograms. The average Body Mass Index value is 23 ± 2,386 kg/m^2. Based on the respondents' personal data, the respondents fall into the ideal category of a volleyball athlete; however, the respondents cannot be said to have a standard posture for a professional athlete because to be classified as a professional athlete, they must have an average height of 1.9 meters, as stated by Fuchs et al., [10] who emphasize that body posture influences the height and results of the jumps made.

The data in table 2 describes the open spike kinematic data in the study, which is divided into four phases: 1) preparation, 2) jumping, 3) impact, and 4) landing. Overall, the data from the kinematic analysis of the open spike technique shows that the average open spike speed was 1.26 ± 0.380 m/s, with a circuit time of 1.98 ± 0.138 seconds for the open spike implementation. The obtained time data is useful for spike movements in scoring points during the match. The distance of repulsion until the legs lands was 2.49 ± 0.750 meters, measured by passing the ball from the setter in front of the net. The distance of repulsion until the legs land was 2.49 ± 0.750 meters, measured by passing the ball from the setter in front of the net. If the setter's pass did not match, the athlete did not continue the movement to do an open spike. In the preparation phase, the open spike technique produced an average leg flexion angle of 129.2 ± 39.667 degrees, a torso extension angle of 164.7 ± 9.225 degrees, and an arm rotation angle of 25.8 ± 20.563 degrees. The average repulsion time during the repulsion phase was 1.01 ± 0.134 seconds, with a leg flexion angle of 103.5 ± 7467 degrees. In the jumping phase, the average torso extension angle was 157.7 ± 11.801 degrees, with an average arm rotation angle of 40.5 ± 24.960 degrees and an average elbow flexion angle of 153 ± 18.027 degrees.

Table 2. Kinematic Data of Open Spike Technique

Indikator	Mean ± SD	Min	Max
Spiking speed (m/s)	1,26 ± 0,380	0,57	1,92
Spiking timing (s)	1,98 ± 0,138	1,78	2,32
Jumping height (m)	2,49 ± 0,750	1,15	3,74
Preparation Phase			
Leg Flexion Angle (°)	129,2 ± 39,667	26	163,9
Torso Extension Angle (°)	164,7 ± 9,225	152,3	179,2
Arm Rotation Angle (°)	25,8 ± 20,563	3	75,1
Jumping Phase			
Jumping Timing (s)	1,01 ± 0,134	0,86	1,28
Leg Flexion Angle (°)	103,5 ± 7467	89,2	116,8
Body Torso Extension Angle (°)	157,7 ± 11,801	133,5	174,5
Arm Rotation Angle (°)	40,5 ± 24,960	7	77,3
Elbow Flexion Angle (°)	153 ± 18,027	128,1	177,4
Impact Phase			
Contact Point (s)	0,57 ± 0,028	0,5	0,62
Jumping Height (m)	4,8 ± 1,510	3,54	7,12
Leg Extension Angle (°)	147,8 ± 28,695	99,6	179,7
Torso Extension Angle (°)	167,1 ± 11,92	144	178,8
Arm Rotation Angle (°)	160,3 ± 14,789	127,4	178,4
Elbow Flexion Angle (°)	166,4 ± 6,178	155,4	178,9
Landing Phase			
Landing Time (s)	0,39 ± 0,075	0,3	0,56
Leg Flexion Angle (°)	141,3 ± 28,531	89,2	178,8
Torso Extension Angle (°)	159,8 ± 14,073	129	176,4
Arm Rotation Angle (°)	47,3 ± 14,073	17,1	139,5
Elbow Flexion Angle (°)	179,9 ± 36,354	67	179,9

The average time obtained during the impact phase was 0.57 ± 0.028 seconds, and the jump height was 4.8 ± 1.510 meters. This phase produced an average leg extension angle of 147.8 ± 28.695 degrees and an elbow flexion angle of 166.4 6.178 degrees. Meanwhile, the average landing time was 0.39 ± 0.075 seconds, with a leg flexion angle of 141.3 28.531 degrees and a torso extension angle of 159.8 14.073 degrees. The athlete was expected to be able to use both legs simultaneously during this landing phase. Athletes should prioritize balance movement when landing to avoid injury. Serrien et al., [36], discovered that when landing on the ground with both feet together, the momentum of the legs can reduce the risk of injury. As a result, optimal spike results support performance while also preventing injury. The average rotation angle of the arm in this phase of the movement was 47.3 ± 34.867 degrees, and the elbow flexion angle was 179.9 ± 36.354

degrees. This information would help athletes optimize arm swing when impacting the ball in the air.

3.2. Discussion

The open spike technique of volleyball athletes in this study has been measured based on the spike pen motion indicator as described by Zahálka et al., [43], with four phases including: 1) preparation phase, 2) jumping phase, 3) impact phase, and 4) landing phase. The results of the kinematic data presented in table 2 with the speed indicator are presented in the following figure.

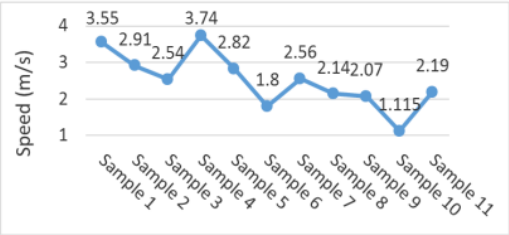

Figure 1. Data of Open Spike Speed

According to figure 1, the open spike average speed of volleyball athletes in Semarang City was 2,494 m/s. Sample 4 had the highest velocity value of 1.93 m/s, while sample 10 had the lowest velocity value of 0.58 m/s. The speed with which open spikes were performed, beginning with the preparation, jumping, impact, and landing phases, can streamline the movement and allow the open spiker to hit the opponent.

In this study, the series of open spike motion began with two steps before going to the jumping phase, then continued by floating in the air until an impact/contact point occurred, and finally landing on the ground. The last phase was longer when doing approaching, there would be a change in speed to acceleration at the end of the movement. In this research, the length from the preparation phase to the jumping phase was not calculated; instead, the distance data from the jumping phase to the landing phase was calculated to determine the results of the repulsion performed and the effect of the impact performed. The motion covered a total distance of 2.49 meters. The researchers present the distance from approaching/jumping to landing in figure 2 below to help readers determine the distance from approaching/jumping to landing. According to figure 3, the data on the distance from approaching/jumping to landing show that sample 10 had the shortest result of 1.15 m. Meanwhile, sample 4 shows the greatest repulsion distance with a result of 3.74 m. The data generated by sample 1 is 3.55 m, 2.91 m in sample 2, 2.54 m in sample 3, and 3.74 m in sample 4. Sample 5 produced a jumping distance of 2.82 m, sample 6 produced a distance of 1.8 m, sample 7 produced a distance of 2.56 m, sample 8 produced a distance of 2.14 m, and sample 9 produced a distance of 2.07 m. The distance between samples 10 and 11 was 1.15 m and 2.19 m, respectively. When performing footsteps within preparation phase, the long stride and small torso angle assist in moving the heel of the dominant foot forward. This promotes efficient movement towards the jumping phase, which maintains balance until the ball's impact phase. The data from this study also revealed that the average angle of extension of the torso during the repulsion phase was 157.7 ± 11.801 degrees. This extension movement prepares the body to whip on impact, adding a spike power to the opponent's court.

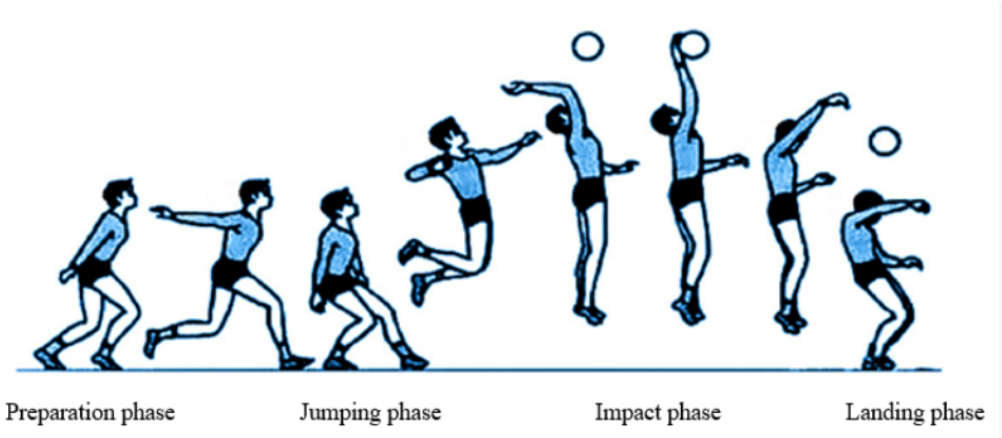

Figure 2. Open Spike Motion Phases

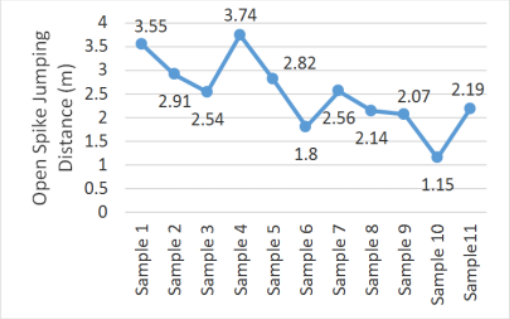

Figure 3. Data of Open Spike Jumping Distance

The timing of the open spike motion was divided into four stages: approaching/jumping, impact, landing, and overall time in the series. The time began when the first footstep completely touched the ground. Figure 4 depicts the overall open spike time series data from this study.

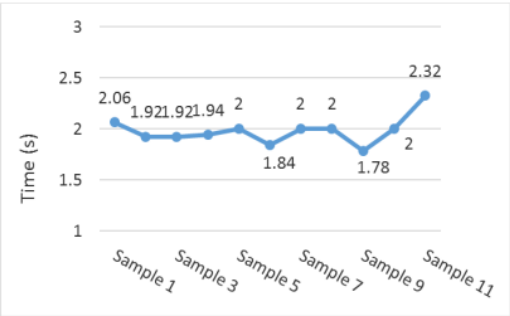

Figure 4. Data of Open Spike Motion Time Series

Figure 4 illustrates the total time of the fastest open spike motion series obtained by sample 11 (2.32 seconds). However, sample 9 produced the slowest time, with a result of 1.78 seconds. Figure 4 also shows the distribution of open spike motion time based on phases, namely the approaching/jumping phase, the impact phase, and the landing phase. The results of the time in the jumping phase are as follows: sample 1 took 1.18 seconds, sample 2 took 0.96 seconds, and sample 3 took 0.90 seconds. Sample 4 produced a time value of 1.02 seconds, while samples 5 and 6 produced time values of 1.10 seconds and 0.92 seconds, respectively. Sample 7 required 1.06 seconds; sample 8 required 0.98 seconds; samples 9 and 10 required 0.86 seconds; and sample 11 required 1.28 seconds. In terms of measuring the open spike movement time during the impact phase, sample 1 achieved a time of 0.50 seconds, followed by samples 2 and 3 that took 0.58 seconds, and sample 4 took 0.56 seconds. Sample number 5 took 0.58 seconds, sample number 6 took 0.62 seconds, and sample number 7 took 0.56 seconds. Sample 8 took 0.56 seconds to complete the open spike motion; sample 9 and 10 took 0.58 seconds; and sample 11 took 0.58 seconds. The open spike time in the landing phase shown by sample 1 was 0.28 seconds; sample 2 was 0.28 seconds; sample 3 was 0.44 seconds; and sample 4 was 0.36 seconds. In sample 5, the time required for completing open spike motion was 0.32 seconds; then sample 6 was0.30 seconds; sample 7 was 0.38 seconds; and sample 8 was 0.46 seconds. Furthermore, the result of the open spike time in sample 9 was 0.34 seconds; then sample 10 was 0.56 seconds; and the last, sample 11 was 0.46 seconds.

The jumping phase is distinguished by the player preparing to jump while using the dominant foot position as a support and the knee in flexion angle. The focus on the dominant leg when making a jump supported by good lower leg muscle strength will form a good leg flexion angle as well. As a result, the resulting jump will be even greater. The average leg flexion angle during the jumping phase was 103.5 ± 746.7 degrees, with the right foot as the dominant foot. When preparing for a jump, the athlete's legs should be open but not too wide. This allows the athlete to transfer speed efficiently for the jump. During the jumping phase, the segment angle produced a torso extension angle 157.7 ± 11.801 degrees, an arm rotation angle 40.5 ± 24.960 degrees, and an elbow flexion angle 153 ± 18.027 degrees. If the lower leg flexion angle is small, it indicates that weak lower leg muscle strength can influence the height of the jump. Additionally, the contours of the athlete's foot in the form of a flat foot or arch foot can affect the explosive power of the legs when jumping [17].

Research on the analysis of volleyball spike motion conducted by Serrien et al., [36], explained that the analysis for men and women in elite junior volleyball players in the spike, that is offensive action is very important to do. Senior class players have a higher impact speed and jump height than juniors. The initial step on the spike made will have an impact on the force generated when jumping (take off) [33]. Kuhlmann et al., [18], found that training jump coordination can also improve reaction time when doing open spikes [14]. The vertical speed during the take-off position can affect the height of the jump as well as the success rate of an open spike. This is consistent with the findings of Zahálka et al., [43], who revealed that explosive movements and vertical jumps during takeoff contribute to the spike. Several determining factors are required to perform the open spike movement, including: (1) preparatory or initial steps, (2) take-off or jumps, (3) hitting the ball while the ball is flying in the air, and (4) landing [1]. The ability of the body's joints, shoulders, legs, and arms influences the success rate of an open spike in volleyball. If every ability in the limbs can be optimized it will produce a strong open spike that is difficult to return [4]. Information that is important to note is that athletes and coaches must always pay attention to the movement techniques and can immediately execute them correctly on the field. Before doing the open spike, an athlete must find the right momentum to execute a pass from the setter to become a point. When the body is in a floating position or before getting into the impact phase,

the dominant arm used to perform the open spike is focused on taking the initial steps and preparing for maximum energy, while the other hand aims at the position of the ball at an angle of arm rotation. The average rotational angle of the arm formed by the sample in this study was 160.3 degrees. This would help maximize arm swing and rotation during impact.

Regarding the movement at arm speed which contributes to the open spike performance in this study, it can be influenced by the momentum of the upper extremity body and very minimally if it is influenced by the strength of the shoulder joint. However, the coordination between the arms and the upper body [11] in doing this open spike makes the athlete's performance increase, especially when the impact is done. Information related to arm performance is also supported by research results which show that the angle of leg extension in the impact phase was 147.8 ± 28.695 degrees with a torso angle was 167.1 ± 11.92 degrees. With good coordination between the upper and lower extremities, it is not possible for athletes to show their maximum performance. Based on research conducted by Pramantiara & Herdyanto, [22], the arm flexion angle that produces optimal power shows a figure of 63 degrees. In contrast to this study, which formed a flexion angle based on when the athlete's arm touched the ball at impact with a value of 166.4 ± 6.178 degrees. This very large data difference can be explained from the point of view of the angle of flexion or extension of the angle of the segment used.

The cause of the difficulty with open spikes in athletes is motion errors. A common mistake athletes make when carrying out an open spike is hitting a ball that often concerns the net because it was hit under the batter's shoulder or at a very close body distance to the net. When you want to open spike, the batter shouldn't get too close to the ball before the ball is at half the distance between the batter and the tosser [20].

Another mistake that often occurs in male and female athletes is the stiffness of the arms when moving. In line with research Putri et al., [28] and Yudi & Anggara, [41], the average athlete, when doing an open smash, move forward, but the arm swing still looks stiff, and the jump is not optimal.

It is important to pay attention to numerous aspects that assist or have an impact on open spike skills to improve each athlete's performance. particularly on hand-eye coordination, arm, and leg strength. This is supported by the findings of the study done by Nasution [19], Pratama [23], Syukur [39], dan Febriansyah & Nurkholis [9], who found that arm muscle strength significantly affects volleyball open spike performance, with stronger arm muscles producing higher results. For volleyball hollow spike skills, characteristics like arm strength, eye-hand synchronization, and self-confidence are just as crucial as arm muscles.

According to research conducted by Santoso & Setiabudi [33], it is known that every step can affect the athlete's power performance. In line with the research conducted by Santoso & Irwanto [32], the number of prefixes will have a major effect on the power produced. Based on research (Hakim & Sukamto, [12]; Anwar et al., [3]), in the game of volleyball, to get numbers or to obtain victories, various ways or techniques can be used, one of which is this initial stage that is very important. Based on research Rahmi & Bachtiar, [31] it is stated that the jumping stage is very important because, at this stage, it is the key to the next step. The jumping stage must be familiarized so that it becomes an automatic movement when going to make a jumping movement to get the maximum blow [37]; [6]; [42]. Therefore, it is crucial for volleyball athletes to master the initial smash technique so that the prefix/jumping movement can be done precisely and efficiently.

In the sport of high jump volleyball, it will produce a more directed spike and deadly hard punches because of its easier range and can save more effort during the game. Athletes who have a high jump have more energy savings by being followed by the spike process in the shortest time or relatively fast, and if the ball athlete has a relatively low jump that will produce a bad spike, then the opponent can more easily calculate the fall of the ball on the spike as well as the speed of time in doing the open spike [29].

Biomechanics in sports can be utilized in the process of improving performance and preventing injuries as early as possible [22]. With the analysis of open spike motion, it is hoped that it can help every athlete improve their performance. So that every movement produced is effective and follows what is desired. In addition, an understanding of the correct movement of a technique to achieve maximum results must be given to athletes as detail as possible so that the basic concepts and knowledge of basic techniques become a strong foundation for training to the next stage such as skill improvement. The performance of the athlete himself is not only based on knowledge of good techniques alone but must also be supported by good physical abilities. The elements of physical ability that every volleyball athlete needs to have are strength, flexibility, agility, speed, and endurance [40].

In a study conducted by Sastra et al., [35], it was also mentioned that the flexibility of the torso affects the results of the open spike, where the more flexible the torso, the better the results of the open spike movement.

A variety of exercises are also required to improve the athlete's ability to open-spike. According to Purba & Hasibuan [25], variations in exercises on spike can increase the results of open spike movements. By doing repeated variations of exercises, you can prevent the possibility of boredom while training, and therefore, your results will experience a significant increase.

This research was limited to the results of the data which was only in the form of kinematic data. Further research should be able to discuss kinetic data like explosive leg power on the success rate of the open spike.

4. Conclusion

According to the results of this study, the open spike motion analysis produced an average jumping time 1.01 seconds and an impact time 0.57 seconds. In the impact phase, the results of the leg extension showed a figure of 147.8 degrees with an arm rotation angle160.3 degrees. This demonstrates that the spike performed by the sample was quite effective. However, if the torso extension movement is maximized, an open spike motion series would be more optimal. The goal of this maximization was to increase the energy of the arm when striking at impact. The research data also shows that athletes need to improve their performance in actual competition situations. The limitation of this study is that it only presents kinematic data. We can discuss the significance of kinetic data and how it affects the success rate of the open spike carried out in future research.

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