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Research Article

Three-Dimensional Kinematic Analysis and Research on the Strong Volleyball Spike Technique of Excellent Female Volleyball Spikers from China and Abroad

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Abstract

This paper uses three-dimensional camera and technical statistics to analyze and study the spiking technique of Chinese and foreign excellent female volleyball attackers. The results show that the speed of Chinese and foreign women's volleyball spikers is close to 4m/s, the maximum ball speed is close to 30m/s and the hitting height is more than 2.9m; the air hitting action is with obvious forward movement. There is a gap between Chinese women's volleyball spikers and excellent foreign attackers in terms of spiking success rate, hitting height and hitting speed.

Keywords: Chinese and foreign women team; 3d kinematics; Comparison and analysis; Difference reason

Preface

Spiking is the most used offense in Chinese and foreign women's volleyball, and the spiking ability of the chief spiker is also an important indicator to measure the offensive strength of a team. From the statistics and analysis, it can be seen that the chief spiker of European and American women's volleyball teams occupy more seats in the top ten positions in the ranking of spike technique in previous international competitions, while the spike success rate of foreign excellent chief spiker is close to 50%; while the spike success rate of Chinese chief spiker Wang Yimei and Hui Ruoqi is around 40%, with a difference of nearly 10 percentage points between them. Therefore, it is necessary to analyze and study the structure and difference of the spike action of Chinese and foreign excellent attackers, in order to outline the technical model of Chinese and foreign excellent attackers' spike and seek some short comings or defects of Chinese attackers.

Research Subjects and Methods

Research Subjects

The spiking technique actions of outstanding female volleyball athletes from China and abroad are the research subjects. The top ten ranked teams in today's women's volleyball world, and their representative athletes are the main objects of measurement and investigation, mainly including related athletes from women's volleyball teams from the United States, Brazil, Italy, China, Japan, and other countries.

Research Methodology

Literature method: Through the Chinese periodicals network and the master's thesis network, "volleyball spiking", "volleyball technology", "three-dimensional analysis of volleyball technology", "volleyball mechanics ", "action analysis", "volleyball kinesiology", "volleyball" and other words as the title, key words, topics to download and read the relevant professional articles. It provides a reliable basis for grasping and analyzing the athletes' technical movements and comparisons.

Three-dimensional image analysis method: In this study, the three-dimensional image analysis method was used to capture the technical movements of Chinese and foreign outstanding female volleyball players in the 2010 World Volleyball Grand Prix Ningbo Final, 2011 World Volleyball Grand Prix Beilun Station, Luohe Station and Quanzhou Station, 2012 World Volleyball Grand Prix Foshan Station, and 2011-2012 Chinese Volleyball League Final Match, etc. The three-dimensional image shooting was carried out.

Filming equipment: four Japanese Panasonic M9000 cameras

Filming frequency: 50fps

Filming method: This study used the DLT 3D synthesis method to construct the 3D space.

As shown in Figure 1 and Figure 2, two cameras were used as a group of two groups, each group of two cameras were fixed

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Table 1:

Country	Name	Height (cm)	Weight (kg)	Spike height (cm)	Women's Volleyball World Cup 2011				2012 Olympics			
					Number of spikes	Scoring Rate	Efficiency	Rank	Number of spikes	Scoring Rate	Effi-ciency	Rank (Effiency)
China	Hui Ruoqi	189	70	312	348	39.94%	27.30%	11	236	35.59%	19.07%	20
Japan	Saori Kimura	185	65	304	360	41.94%	30.83%	5	339	39.23%	25.66%	12
China	Tom Logan	186	80	306	196	36.73%	25.00%	20	179	34.08%	23.46%	14
America	Wang Yimei	190	90	318	288	38.89%	22.92%	14	137	37.96%	21.17%	18
Italy	Gsta Grande	188	80	312	380	43.95%	37.37%	4	196	34.18%	22.96%	16
Brazil	Jacqueline	186	70	302	-	-	-	-	189	42.33%	32.28%	6

Table 2: Summary of data related to the spiking and running phases of Chinese and foreign outstanding spikers.

Name	First step		Second step		Third step		Last step away (m)	Assist speed (m/s)	Assist distance (m)
	Stride length (m)	Speed (m/s)	Stride length (m)	Speed (m/s)	Stride length (m)	Speed (m/s)			
Hui Ruoqi	0.847	1.606	1.019	2.653			0.797	3.678	2.12
Tom Logan	0.592	0.608	0.655	2.228	1.203	3.85	0.774	4.121	2.84
Saori Kimura	0.502	1.671	0.956	2.912			0.901	3.835	2.01
Costa Grande	0.716	2.134	1.23	3.312			0.77	4.422	1.88
Wang Yimei	0.68	1.947	1.167	2.8			0.857	3.198	2.08
Jacqueline	0.818	3.912	1.158	5.899			0.834	3.778	2.72
Average ($\overline{x}$)	0.69	1.98	1.03	3.30	-	-	0.82	3.84	2.28

at the side and back of the field and made the main optical axis approximately intersect at right angles, the two groups of cameras were aimed at the area of the court 2 and 4 positions. Before each shooting game, through the use of Agile three-dimensional frame for the No. 2 and No. 4 position for the calibration, frame placement as shown in the figure, frame calibration three-dimensional space for the two cameras to shoot crossed side length of about 5m square, x axis, y axis, z axis direction as shown in the figure.

Analysis method: The APAS XP three-dimensional action analysis system of Ariel, USA was used to analyze the technical movements of excellent volleyball players. The image analysis was performed field by field for each player's spike technical action, from jumping to hitting the ball in the air until landing on the cushion, and the 3D coordinate values of each part of the body from head to foot were calculated for each frame, mainly including displacement, distance, speed, height and other related indexes.

Data smoothing: In this study, low-pass digital filtering was used for smoothing, with a truncation frequency of 8Hz.

Synchronization method: This study adopts the external synchronization method for image synchronization, using the snap shot moment as the synchronization screen, and the synchronization correction function of APAS system for image synchronization correction.

Error analysis: In this study, the error detection was carried out within the calibration range of the frame by 1m fixed-length markers in parallel with the X, Y and Z-axis directions respectively, which was digitally verified to be 0.013±0.002 m for the X-axis direction, 0.013±0.004 m for the Y-axis direction and 0.008±0.003 m for the Z-axis direction.

Video observation and technical statistics method: Video observation and technical statistics were conducted on the obtained videos related to 2010 World Women's Volleyball Championship, 2011 Women's Volleyball World Cup matches, 2012 London Olympic Games women's volleyball matches, 2010-2012 World Women's Volleyball Grand Prix and so on, with reference to some authoritative index data of the International Volleyball Federation and combined with volleyball-related professional knowledge. We collect and organize the data of relevant technical use for the athletes of relevant filming and measurement, and conduct description and analysis of technical characteristics by observing and comparing with live matches.

Results and Analysis

Three-Dimensional Kinematic Analysis of Spiking Techniques of Excellent Female Volleyball Players in China and Abroad

The spiking technique can be analyzed as a process that can be broken down into several steps, including the preparatory posture, approach, jump, mid-air strike, and landing. However, in terms of the impact on the effectiveness of the spike, the approach, jump, and mid-air strike are undoubtedly the most critical steps. Therefore, these three technical elements are the focus of analysis, aiming to explore the main action parameters and differences of Chinese and foreign excellent athletes. As a major starting point for the spike action, the approach is essential for obtaining a good take-off position, appropriate take-off speed and angle, and considering the trajectory and condition of the incoming ball. When selecting actions, the basic assumption is that the player No.4 faces similar incoming balls during attacks, assuming that the first pass is in place and the second pass allows sufficient time for organization. However, differences in the approach are mainly due to the attacker's judgment of the ball's time and space, utilization of their own jumping height, recognition and adjustment of their movement speed, and anticipation of the ball's trajectory and the position of the opposing team.

Analysis of the Running Assists of the Strong Attacking Spike of Chinese and Foreign Excellent Female Volleyball Players

There are one step, two steps, three steps or more steps, and in-situ pads in the running aid. From the video observation and analysis of the game, the athletes are hardly in a stationary state after the start of the game serve, but the observation of the process of preparation and final contact with the ball before

Table 3: Angles of the joints of the lower limbs in each phase of the jumping process of the spiking of Chinese and foreign excellent spiker.

Name	Joint angle at the moment of landing(°)						Joint angle at maximum cushioning(°)						Instantaneous joint angle off the ground(°)					
	Left ankle	Left knee	Left Hip	Right ankle	Right knee	Right hip	Left ankle	Left knee	Left Hip	Right ankle	Right knee	Right hip	Left ankle	Left knee	Left Hip	Right ankle	Right knee	Right hip
Hui Ruoqi	95.158	129.884	105.692	84.735	125.029	118.431	93.89	125.868	123.23	63.081	120.663	161.376	114.204	166.709	175.592	95.942	152.819	159.981
Tom Logan	119.458	156.22	124.764	90.592	132.793	75.418	123.578	160.66	148.055	66.973	112.4	61.464	104.637	155.92	151.856	129.849	175.869	174.762
Saori Kimura	120.785	151.754	123.414	98.437	136.748	123.673	96.025	124.504	145.566	61.217	101.506	120.468	127.73	167.449	166.185	150.573	151.229	156.908
Gsta Grande	101.623	147.303	132.032	104.99	163.685	111.276	97.122	148.137	145.795	97.794	157.124	113.22	116.099	169.684	166.402	111.146	146.566	153.557
Wang Yimei	95.759	126.118	113.636	93.931	147.532	122.563	103.838	146.077	149.961	73.171	121.115	134.114	119.586	168.772	176.242	122.295	157.641	156.117
Jacque-line	122.11	173.083	129.41	119.36	143.76	105.02	132.73	164.92	161.41	61.719	101.86	133.964	136.237	171.57	170.27	128.25	152.632	175.206

Table 4: Shows the joint angle changes of the buffered jump and push-off during the spike take-off for excellent Chinese and foreign spikers.

Name	Joint angle during cushioning (°)						Joint angle during stirrups and extensions (°)					
	Left ankle	Left knee	Left Hip	Right ankle	Right knee	Right hip	Left ankle	Left knee	Left Hip	Right ankle	Right knee	Right hip
Hui Ruoqi	1.268	4.016	-17.538	21.654	4.366	-42.945	20.314	40.841	52.362	32.861	32.156	-1.395
Tom Logan	-4.12	-4.44	-23.291	23.619	20.393	13.954	-18.941	-4.74	3.801	62.876	63.469	113.298
Saori Kimura	24.76	27.25	-22.152	37.22	35.242	-3.205	31.705	42.945	20.619	89.356	49.723	36.44
Gesta Grande	4.501	-0.834	-13.763	7.196	6.561	-1.944	18.977	21.547	20.607	13.352	10.558	40.337
Wang Yimei	-8.079	-19.959	-36.325	20.76	26.417	-11.551	15.748	22.695	26.281	49.124	36.526	22.003
Jacqueline	-10.62	8.165	-32.005	57.637	41.894	-28.95	3.51	6.649	8.852	66.528	50.768	41.242
Average ($\overline{x}$)	1.29	2.37	-24.18	28.01	22.48	-12.44	11.89	21.66	22.09	52.35	40.53	41.99

Table 5: Summarizes the buffered jump and push-off time during the spike take-off for excellent Chinese and foreign spikers.

Name	Left foot jump					Right foot jump				
	Buffer time (s)	Puff-off time(s)	Total (s)	Buffer ratio	Puff-off ratio	Buffer time (s)	Puff-off time (s)	Total (s)	Buffer ratio	Puff-off ratio
Hui Ruoqi	0.06	0.12	0.18	33.33%	66.67%	0.22	0.1	0.32	68.75%	31.25%
Tom Logan	0.06	0.12	0.18	33.33%	66.67%	0.16	0.18	0.34	47.06%	52.94%
Saori Kimura	0.06	0.14	0.2	30.00%	70.00%	0.18	0.16	0.34	52.94%	47.06%
Gesta Grande	0.08	0.12	0.2	40.00%	60.00%	0.04	0.26	0.3	13.33%	86.67%
Wang Yimei	0.1	0.14	0.24	41.67%	58.33%	0.14	0.18	0.32	43.75%	56.25%
Jacqueline	0.08	0.06	0.14	57.14%	42.86%	0.2	0.1	0.3	66.67%	33.33%
Average ($\overline{x}$)	0.07	0.12	0.19	39.25%	60.76%	0.15	0.17	0.32	48.75%	51.25%

Table 6: Summarizes the jump height, distance, speed, and take-off angle for excellent Chinese and foreign spikers.

Name	Jump height(m)	Jumping distance(m)	Jumping speed(m/s)	Jump angle (°)
Hui Ruoqi	0.82	0.97	4.133	43.9
Tom Logan	1.002	1.3088	4.399	54.0
Saori Kimura	0.752	1.642	4.564	50.8
Gesta Grande	0.475	1.3714	3.756	56.7
Wang Yimei	0.485	1.3715	3.557	67.0
Jacqueline	0.785	1.63	3.525	52.1
Average ($\overline{x}$)	0.72	1.38	3.99	54.08

Table 7: Summarizes the relevant parameters of the spike hitting in the air for excellent Chinese and foreign spikers.

Name	Hitting height(m)	Height of center of gravity when hitting the ball(m)	Maximum center of gravity height(m)	Center of gravity speed(m/s)
Hui Ruoqi	2.85	1.718	1.733	2.853
Tom Logan	3.063	1.747	1.747	4.743
Saori Kimura	2.838	1.718	1.721	3.562
Gesta Grande	2.96	1.298	1.319	3.198
Wang Yimei	2.93	1.611	1.64	2.593
Jacqueline	2.86	1.665	1.666	3.046
Average ($\overline{x}$)	2.92	1.63	1.64	3.33

Table 8: Summarizes the relevant parameters of the spike hitting moment during the spike take-off for excellent Chinese and foreign spikers.

Name	Instantaneous speed of each link at the time of hitting the ball (m/s)				Maximum velocity of the ball(m/s)	Arm and torso angle(°)
	Shoulder	Elbow	Wrist	Fingertips		
Hui Ruoqi	3.414	7.061	10.23	11.761	23.70	146.697
Tom Logan	4.905	9.559	15.345	18.472	28.849	156.769
Saori Kimura	4.379	7.552	13.009	16.388	20.515	159.689
Gesta Grande	3.663	7.649	11.756	13.721	14.533	133.019
Wang Yimei	2.602	7.39	10.692	12.736	24.449	157.778
Jacqueline	3.641	6.224	10.259	12.525	34.138	148.458
Average ($\overline{x}$)	3.77	7.57	11.88	14.27	24.36	150.40

the athletes buckle, the athletes have obvious stopping action before adjusting the action and running aid, thus this can be used as the starting point for judging the athletes to start running aid. From Table 4-2, it can be seen that there are more two-step assisted running steps used by Chinese and foreign excellent attackers, and only Tom Logan of the United States uses three-step assisted running. When two-step assist, the first step should be small in order to find and correct the direction of the upper step, so that the stationary body can gain forward speed; the second step should be large to facilitate the approach to the ball, while the body leans back to facilitate braking. From Table 2, it can be seen that the athletes' assisted running traits also conform to such a rule. The stride length of the second step of the assisted running is all larger than the stride length of the first step, and the stride length of the assisted running all have a tendency to increase, and from the analysis of the distance of the parallel stride, the last step distance is all smaller than the last step, and the end of the assisted running is prepared for the final jump, and the distance between the two feet is smaller in order to facilitate the jump.

The speed of the assisted run is the synthetic speed of the center of gravity at the moment of the assisted run, and the speed of each step is the synthetic speed of the center of gravity at the moment of the assisted run. From the results of the study, it can be seen that no matter using two-step or three-step running aid, the speed from the first step to the last step has a tendency to increase, and the speed of the center of gravity at the moment of the parallel step still has a tendency to increase compared with the speed of the center of gravity at the last step of the running aid. The studied subject's assisted running speed is roughly between 3.2-4.4m/s, which can indicate that the assisted running speed of high-level volleyball players is roughly in this range, and this result is similar to the study of Takashihiro Hashibara and Fanfu Dozawa, who concluded that "the maximum speed obtained by the world's leading snapper at the end of assisted running is within the range of 290cm/s-442cm/s, and the optimal value is The results of the study "400cm/s" are similar and have a tendency to increase.

The parallel distance is the distance between the left foot and the right foot after the end of the run. From the results of the study, it can be seen that the last step distance of excellent Chinese and foreign main attackers is 0.77m-0.90m, and the last step distance of 0.8m is more ideal. By analyzing the comparison of the last step distance and running speed of each player, it is known that the size of last step distance has a certain relationship with the speed of the center of gravity at the end of the assist, that is, the speed of the assist. Costa Grande's last step distance is 0.77m, the smallest among all athletes, while its assisted running speed is 4.422m/s, the largest among all athletes; it can be seen that the increase of last step distance can help braking, while the smaller last step distance can retain a larger speed. The running distance refers to the actual distance that the center of gravity moves on the horizontal plane from the moment the athlete begins to run to the moment the athlete strides. From the analysis of the research results, the longest distance of Tom Logan's assisted running is 2.84m, and the assisted running distances of other athletes are all around 2m, which is greatly related to the matter of three steps assisted running used by Tom's spike.

Therefore, from the analysis of the research results, the model of Chinese and foreign excellent attackers' spiking assist link is: two-step diagonal assist, the pace of the first step assist is 0.50m-0.99m, the speed is 0.6m/s-2.6m/s; the distance of the second step assist is about 1m, the speed is 2.2m/s-4.7m/s. The assist speed is 3.2m/s-4.4m/s; and step. The distance is 0.77m-0.90m, the assisted distance is 2m. Chinese player Wang Yimei's assisted speed is 3.198m/s, Hui Ruoqi's assisted speed is 3.678m/s, the latter's assisted speed is slightly faster than the former, but compared with other players obviously slower assisted speed; Skowronska's assisted speed is as high as 4.236m/s, Costa Grande's assisted speed is faster 4.422m/s, so the slow running speed may be one of the reasons for the unsatisfactory effect of Chinese player Wang Yimei's spike.

Three-dimensional kinematic analysis of the jumping link of the spike of chinese and foreign excellent spiker: The purpose of the jump of the spiking technical action is to obtain the suitable height and speed in order to form the suitable angle, height, speed and line for the spiking stroke. According to the jumping action and its obvious time characteristics, the process of jumping can be divided into three characteristic phases: the moment of landing, the moment of maximum cushioning and the moment of leaving the ground. However, some people also divide the jumping action into two phases: cushioning and stretching. There are two classifications of the cushioning and the stirring phases: the first one is based on the characteristics of kinetics: for example, Chen Min-sheng [Chen Min-sheng. Discussion on the Dynamic Effect of Takeoff Step in Long Jump [J]. China Sports Science, 1992, 12(1):75-78.] According to the Fx-T curve obtained from the force measuring table, the moment Fx=0 is taken as the critical point of buffering and stirring, and the moment Fx=0 is the vertical support phase of the human body in the process of stepping and jumping, which is the critical point of transformation from braking force to power. The second is to use the kinematic method: (1) the jumping leg knee angle as the standard, the jumping leg knee joint is the largest role in the jumping process, so its maximum bending is the critical point of cushioning and stirrups; (2) the moment of the jumping lower limb three joint angle are increased as the critical point of cushioning and stirrups. (3) The moment of the lowest point of the center of gravity is the critical point of cushioning and extension. Since the kinematic perspective is convenient for research observation and video collection and

analysis, the kinematic perspective is more realistic. From the research feature screen, most researchers take the maximum bending of the knee joint of the jumping leg as the critical point. Since most of the jumping movements of the spiking use the jumping of both feet in sequence, the maximum bending of the left and right knee joints may exist, and they may not always have good simultaneity and uniformity, therefore, according to the needs of the study, the maximum bending of the right knee joint is used as the critical point in defining the maximum cushioning moment (the lowest point of the auxiliary center of gravity is used as a reference). From the moment of landing to the moment of maximum cushioning was used as the cushioning phase, and from the moment of maximum cushioning to the moment of leaving the ground was the stirrup extension phase. From the selection of the action screen, we can take "the moment of right foot landing", "the moment of lowest center of gravity", "the moment of left foot landing", "the moment of right foot leaving the ground The moment the right foot hits the ground", "the moment the center of gravity is lowest", "the moment the left foot hits the ground", "the moment the right foot leaves the ground" and "the moment the left foot leaves the ground" have distinctive characteristics as the threshold of action.

Table 3 presents the angle values of the ankle, knee, and hip joints of the lower limbs of the relevant athletes at different critical points during the takeoff phase, namely, the angle values of the three main joints of the lower limbs at the moment of ground contact, maximum buffering, and takeoff. From ground contact to maximum buffering is the buffering phase of takeoff, while from maximum buffering to takeoff is the push-off phase. From both the data results and motion pictures, it can be observed that the left and right legs of the athletes differ and both possess jumping traits. Therefore, this study extracted and analyzed data on the angles of the relevant joints on both sides and conducted an analysis to seek commonalities and differences. As all selected athletes were right-handed and spike with their right arm, their right foot leads in landing, and both feet jump sequentially. Thus, the analysis begins with the relevant details of the right foot. At the moment of ground contact, the angle of the right ankle joint ranges from 84° to 105°, with a mean value of 94.5°; the angle range of the right knee joint is 125° to 163°, with a mean value of 142.3°; the angle range of the right hip joint is 75° to 124°, with a mean value of 111.4°. At the maximum buffering moment, the angle of the right ankle joint ranges from 61° to 73°, with a mean value of 72.4°; the angle range of the right knee joint is 101° to 157°, with a mean value of 118.9°; the angle range of the right hip joint is 61° to 119°, with a mean value of 118.4°. At the takeoff moment, the angle range of the right ankle joint is 96° to 151°, with a mean value of 121.9°. The angle range of the right knee joint is 138° to 176°, with a mean value of 153.8°, and the angle range of the right hip joint is 154° to 174°, with a mean value of 160.9°. For the left leg analysis, i.e., the non-dominant leg, at the moment of ground contact, the angle range of the left ankle joint is from 96° to 121°, with a mean value of 107°; the angle range of the left knee joint is 126° to 156°, with a mean value of 140.6°, while the angle range of the left hip joint is 106° to 132°, with a mean value of 120.2°. At the maximum buffering moment, the angle range of the left ankle joint is from 94° to 124°, with a mean value of 103.8°; the angle range of the left knee joint is 125° to 161°, with a mean value of 142.4°, while the angle range of the left hip joint is 123° to 157°, with a mean value of 145°. At the takeoff moment, the angle range of the left ankle joint is from 104° to 127°, with a mean value of 117°, the angle range of the left knee joint is 156° to 170°, with a mean value of 164.8°, and the angle range of the left hip joint is 152° to 176°, with a mean value of 168°. From the analysis, it can be seen that the changes in the angles of the right leg and related joints of the athletes are more obvious, as most athletes use their right leg as the support leg, and its landing, braking, buffering, and other movements are more pronounced. Therefore, from the perspective of their motion effects and influencing factors, the jumping action of the right leg and related movements of the athletes require a more in-depth analysis.

Table 4 shows the angle changes of the relevant lower limb parts during the buffering and push-off phases of the athletes' takeoff. The buffering angle is the difference between the joint angles at the moment of ground contact and the moment of maximum buffering. The push-off angle is the difference between the joint angles at the moment of takeoff and the moment of maximum buffering. As all athletes used their right leg as the first to land, the changes in the relevant parts of the right leg were more obvious, especially the changes in the right knee joint, which had the most significant features. Therefore, a more focused analysis can be conducted on the related changes in the right knee joint. From the table, it can be seen that the range of buffering angle of the athletes' right knee joint is from 4.4° to 47.4°, with a mean value of 22.48°. The range of push-off angle of the athletes' right knee joint is from 10.6° to 63.5°, with a mean value of 40.53°. Comparing the buffering and push-off angles, it can be observed that the mean value of buffering angle is smaller than that of push-off angle. This indicates that athletes tend to focus more on push-off effects than buffering effects during the takeoff process. The mean value of the buffering angle of the right ankle joint is 28.0°, which is smaller than its mean value of the push-off angle, which is 52.35°. The mean value of the buffering angle of the right hip joint is also smaller than that of the push-off angle, which fully demonstrates that athletes pay more attention to the push-off effect during the takeoff phase, and the requirements for buffering are not as high as those for push-off. From the analysis of the buffering and push-off conditions of the left lower limb joints, it can be seen that the buffering angles of the left knee joint and hip joint are negative. This is because when the body's center of gravity reaches its lowest point, the left leg has not yet reached the maximum buffering point. Due to athletes using a left leg step-up takeoff, the buffering of the left leg is relatively small, or even non-existent, resulting in negative buffering angles. However, there were no negative values observed in the analysis of the push-off effect of the athletes' left leg, which fully demonstrates that the requirements for the push-off effect of the left leg are more obvious.

Table 5 shows the time comparison of the two phases of world-class female volleyball players' takeoff. The buffering time is the time from the moment of ground contact to the moment of maximum buffering, and the push-off time is the time from the moment of maximum buffering to the moment of takeoff. The sum of the two is the total takeoff time. The buffering ratio and the push-off ratio represent the percentage of time used in each phase to the total takeoff time. From the table, it can be seen that the average takeoff time of the athletes' right foot is 0.32s, with an average buffering time of 0.15s and an average push-off time of 0.17s. The push-off time is longer than the buffering time, and the proportion of push-off time is higher than that of buffering time during the entire takeoff process. However, the difference between the two is not very significant,

with only a 3% difference, which is similar to the results of the comparison between buffering angle and push-off angle analyzed above. The average buffering time of the athletes' left foot is 0.07s, with an average push-off time of 0.12s, and an average takeoff time of 0.2s. Similarly, the push-off time is longer than the buffering time, and the proportion of push-off time is much higher than that of buffering time. Moreover, the takeoff time of the left foot is significantly shorter than that of the right foot in the entire takeoff process, which is related to the fact that the left foot steps up later than the right foot.

Through the analysis of takeoff time, it can be known that Wang Yimei's takeoff time of the left foot is 0.24s, which is the longest among all the studied athletes. As the takeoff process mostly involves the left foot stepping up and followed by the right foot, a longer takeoff time of the left foot may lead to a slower takeoff rhythm and make it easier for the blocker. By analyzing the takeoff time of Chinese athlete Hui Ruoqi, it can be seen that her right foot buffering time is 0.22s, and the push-off time is 0.1s. The buffering time is significantly longer than the push-off time, which is different from other players. Although longer buffering time can help convert more kinetic energy into potential energy, it will inevitably affect the entire takeoff rhythm and give the blocker more reaction time. Therefore, from the analysis of the takeoff phase, Chinese athletes have the shortcomings of longer takeoff time and higher buffering ratio than push-off ratio.

Table 6 summarizes the athlete's jumping height, distance, velocity, and take-off angle. Jumping height refers to the difference between the athlete's center of gravity height at take-off and their maximum center of gravity height. Jumping distance refers to the actual distance the athlete's center of gravity moves from take-off to landing. Jumping velocity refers to the composite velocity of the athlete's center of gravity at take-off. Take-off angle refers to the angle between the direction of the athlete's center of gravity at take-off and the horizontal direction, which can reflect the distribution of the athlete's vertical and horizontal velocity components at take-off and indicate the allocation of jumping height and horizontal displacement. The results of the study show that the jumping height of excellent female volleyball players from China and abroad ranges from 0.48m to 1.00m, with a mean of 0.72m; the jumping distance ranges from 0.97m to 1.64m, with a mean of 1.38m; the jumping velocity ranges from 3.76m/s to 4.56m/s, with a mean of 3.99m/s; the center of gravity take-off angle ranges from 43.9° to 67°, with a mean of 54.08°. Chinese athlete Hui Ruoqi's center of gravity take-off angle is smaller, which may be related to her forward movement, resulting in a smaller vertical velocity component for jumping height.

Analysis of the data obtained from the study reveals that Wang Yimei's jumping height of 0.485m is only slightly higher than that of Kostagrande by 0.01m, and lower than that of any other player. Insufficient jumping height means that there is not enough space height available to utilize in the air, which leads to fewer opportunities for observation and selection in the air, resulting in a smaller selection of hitting options and hurried hit attempts. Therefore, the lack of jumping height in the air may be the reason for the difference in Wang Yimei's success rate in spiking compared to other attackers. At the same time, we also found that Wang Yimei's take-off angle is relatively large, which indicates that her horizontal velocity component is relatively small, meaning that the space distance for forward displacement is also small. This may affect the forward movement

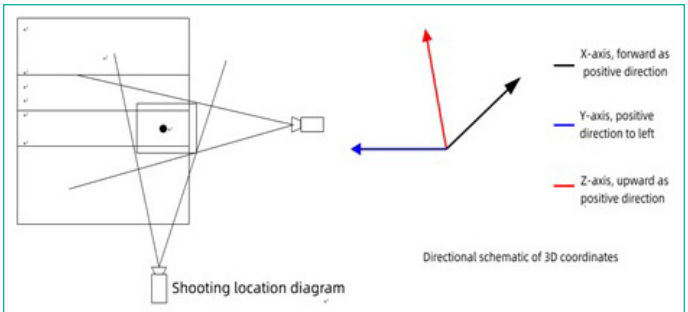

Figure 1: No. 2 area volleyball spike camera position and shooting diagram.

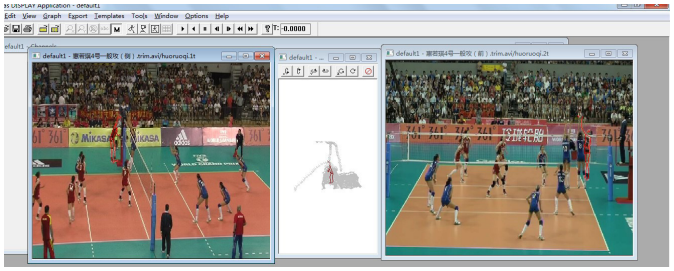

Figure 1: Huo Ruoxi's overall stick figure of spiking and the side and front video images of the moment of hitting the ball.

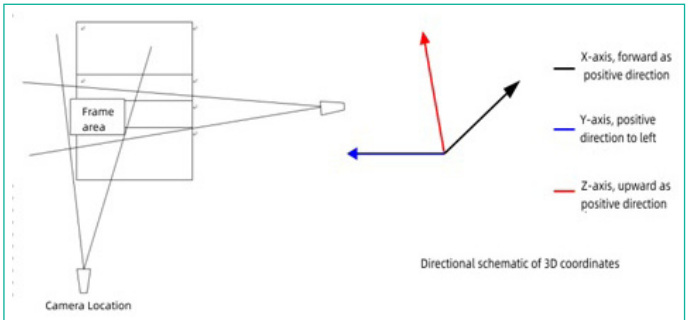

Figure 2: No. 4 area volleyball spike camera position and shooting diagram.

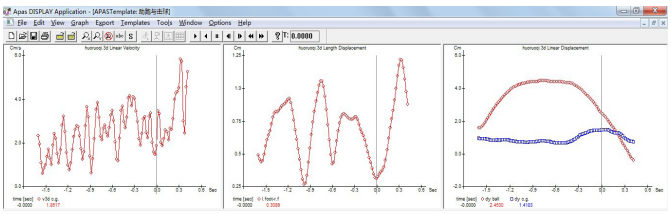

Figure 2: shows the changes in Hu Ruoqi's approach speed, stride length, etc. (speed in m/s, distance in m, height in m). (Note: Due to system settings, the units in the figure are shown in cm, which should be in m, and cm/s should be in m/s.).

before hitting the ball, as evidenced by Wang Yimei's take-off velocity of 3.557m/s. Therefore, the insufficient jumping height and small take-off velocity are the shortcomings in Wang Yimei's spike take-off phase. Analysis of Hui Ruoqi's jumping height is 0.82m, which is good but still lower than that of American player Tom Logan. Hui Ruoqi's jumping distance is 0.97m, and her take-off velocity is also not great. From the analysis of the take-off phase, Chinese attackers have shortcomings in jumping height, jumping distance, and take-off velocity.

Based on this, it can be inferred that the model for the take-off phase of elite spiking athletes in the world is as follows: the takeoff time is 0.32 seconds; the takeoff height ranges from 0.48m to 1.00m, with a mean of 0.72m; the takeoff distance ranges from 0.97m to 1.64m, with a mean of 1.38m; the take-off velocity ranges from 3.76m/s to 4.56m/s, with a mean of 3.99m/s; and the range of the center of gravity lifting angle is 43.9° to 67°, with an average of 54.08°.

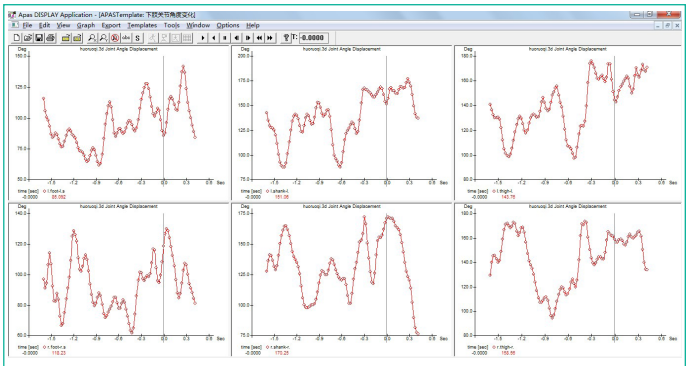

Figure 3: shows the changes in the angles of Hu Ruoqi's ankle, knee, and hip joints in the lower limbs.

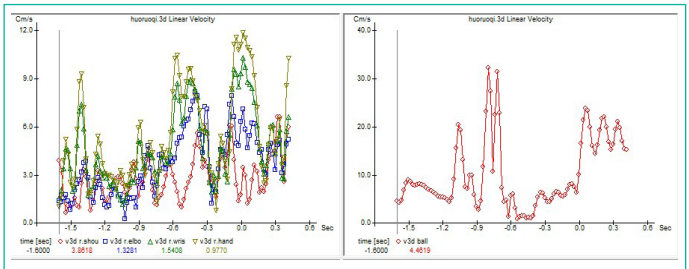

Figure 4: displays the changes in the corresponding segmental velocities and ball speed of Hu Ruoqi at the moment of spike hitting (with units in m/s).

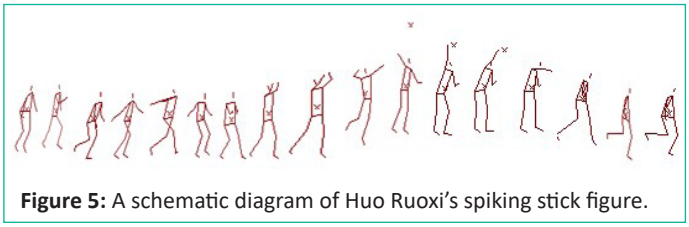

Figure 5: A schematic diagram of Huo Ruoxi's spiking stick figure.

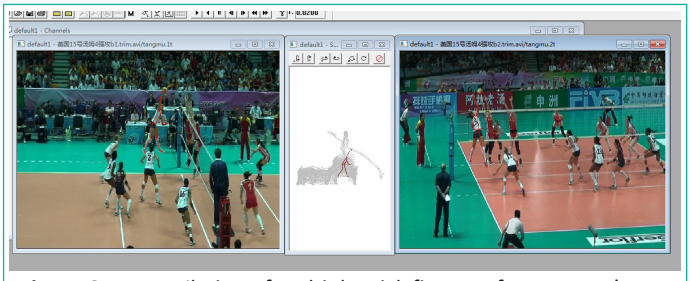

Figure 6: A compilation of multiple stick figures of Tom Logan's spiking and the side and back video images of the moment of hitting the ball.

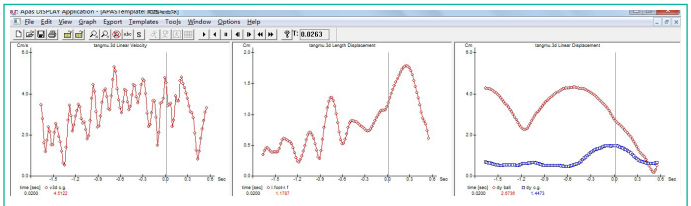

Figure 7: Graphs of Tom Logan's assisted running speed, stride length, center of gravity height and ball height change.

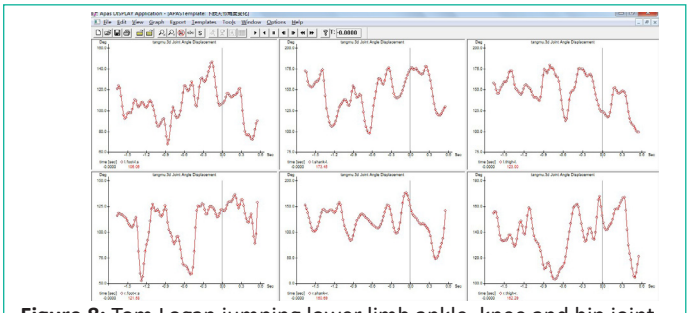

Figure 8: Tom Logan jumping lower limb ankle, knee and hip joint angle change chart.

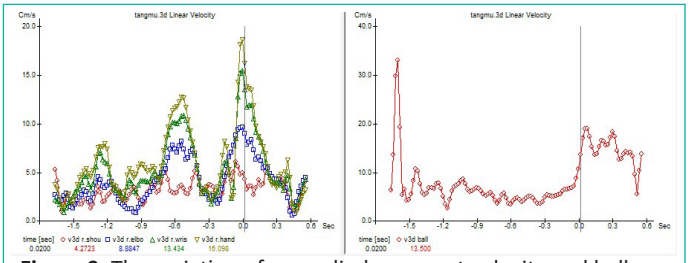

Figure 9: The variation of upper limb segment velocity and ball speed during Tom Logan's hitting.

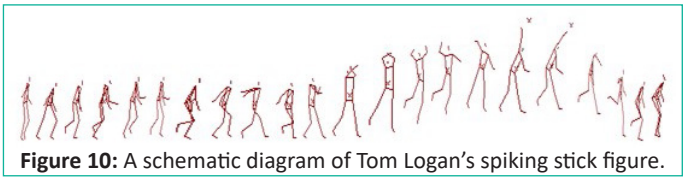

Figure 10: A schematic diagram of Tom Logan's spiking stick figure.

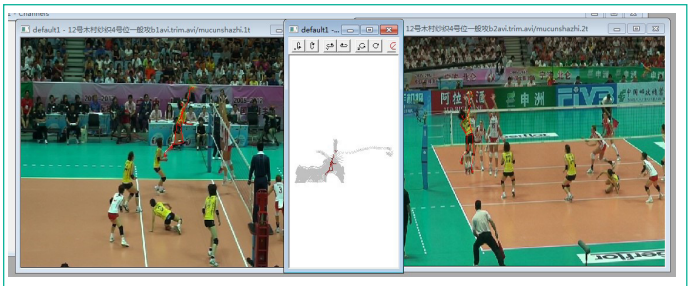

Figure 11: A compilation of multiple stick figures of Saori Kimura's spiking and the side and back video images of the moment of hitting the ball.

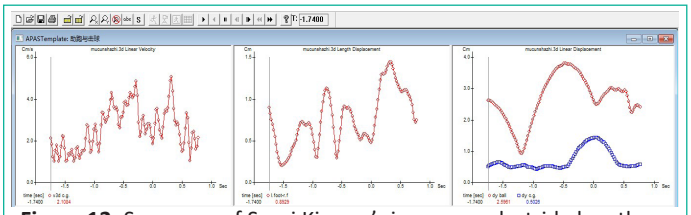

Figure 12: Summary of Saori Kimura's jump speed, stride length, center of gravity height, and ball height.

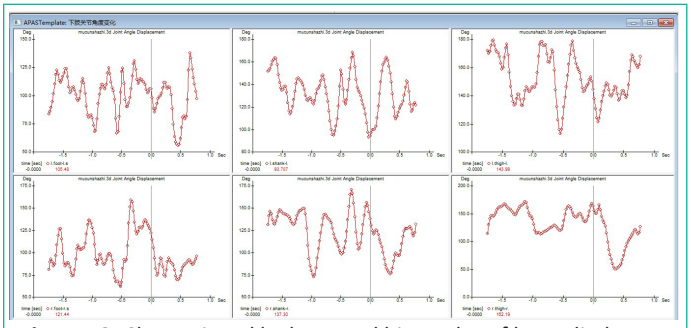

Figure 13: Change in ankle, knee and hip angles of lower limbs during jumping by Saori Kimura.

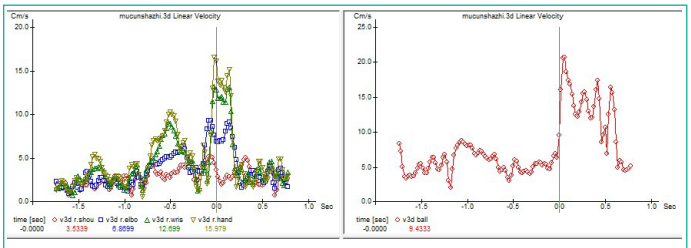

Figure 14: The variation of upper limb segment velocity and ball speed during Saori Kimura's hitting.

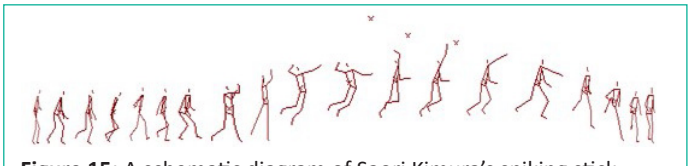

Figure 15: A schematic diagram of Saori Kimura's spiking stick figure.

Three-dimensional kinematic analysis of spike hitting phase of excellent main attacking athletes in the world: The airborne hitting phase is a crucial part of the spiking technique and an important technical component that determines the success or failure of the spike. Factors such as the height, speed, power, trajectory selection, and variations in the technique can ultimately affect the success or failure of the spike. As excellent spikers in the world, their long-term training and competition experience lead to the formation of stable muscle memory and movement habits, which enable them to maintain a relatively constant level of athletic performance. This is also reflected in the relatively fixed mathematical parameters of their technical actions. The hitting height refers to the actual height of the ball at the moment of spiking; the height of the center of gravity at the moment of hitting refers to the actual height of the athlete's center of gravity at the moment of spiking; the maximum height of the center of gravity refers to the actual height at which the athlete's airborne center of gravity reaches the maximum height; and the center of gravity velocity refers to the composite velocity of the athlete's center of gravity at the moment of hitting.

Results showed that the hitting height range of the spike was between 2.85m and 3.06m, with an average of 2.92m; the height of the center of gravity at the moment of hitting ranged from 1.29m to 1.75m, with an average of 1.63m; the maximum height of the center of gravity ranged from 1.29m to 1.75m, with an average of 1.64m; and the center of gravity velocity ranged from 2.60m/s to 4.7m/s, with an average of 3.33m/s. Comparing the height of the center of gravity at the moment of hitting with the maximum height of the center of gravity, it was found that few athletes performed the spike hitting action at the maximum height of the center of gravity during actual competitions. Among the athletes studied, Tom Logan hit the ball at the same height as his maximum center of gravity, while other athletes had differences between their hitting height and maximum center of gravity height, indicating that hitting the ball did not occur when the athlete's center of gravity reached the maximum height.

From the analysis of the research results, it can be seen that the body center of gravity and the highest body center of gravity height are not consistent when Chinese and foreign outstanding female volleyball players hit the ball in the air, and most of the athletes' maximum center of gravity height appears before hitting the ball. Chinese spiker Hui Ruoqi has the lowest height of 2.85m, Wang Yimei has 2.93m, slightly higher than Hui Ruoqi's but still lower than Gesta Grande, Tom Logan and other foreign spikers. The height of Wang Yimei's stroke is 2.93m, which is slightly higher than Huirouqi's but lower than Gesta Grande, Tom Logan and other foreign spiker. From the analysis of the height of the center of gravity when hitting the ball, Tom Logan, Saori Kimura and other foreign spikers have the same height. The height of the center of gravity at the time of hitting is related to the height of the athlete's center of gravity on the one hand, and the body posture in the air after the athlete has risen on the other hand, as well as the grasp of the rhythm of the ball. The low height of Wang Yimei's center of gravity may be related to the low height of her center of gravity and the short retention time of her center of gravity in the air. Thus, the low height of the ball in the air is one of the differences between Chinese spikers and foreign spikers, while Chinese spikers have certain differences in the height of the center of gravity and the lag time.

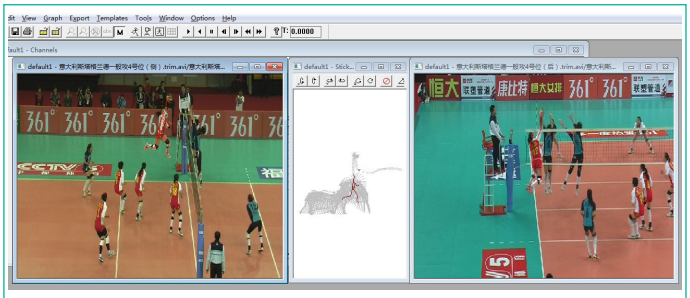

Figure 16: A compilation of multiple stick figures of Gesta Grande's spiking and the side and back video images of the moment of hitting the ball.

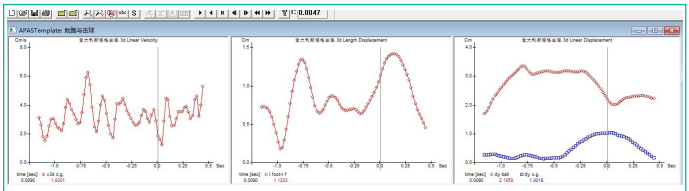

Figure 17: Summary of graphs of Gesta Grande's assisted running speed, stride length, center of gravity height, and ball height.

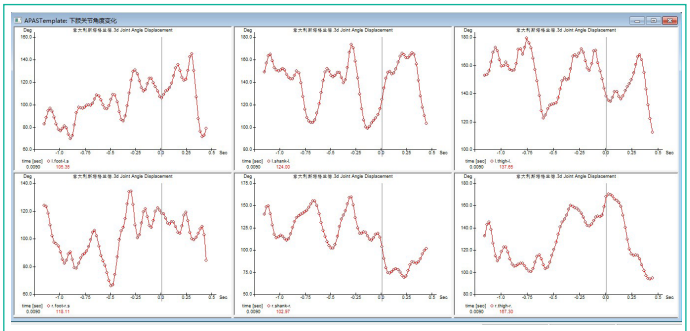

Figure 18: The change of ankle, knee and hip angles of the lower limbs left and right during the jump of Gesta Grande.

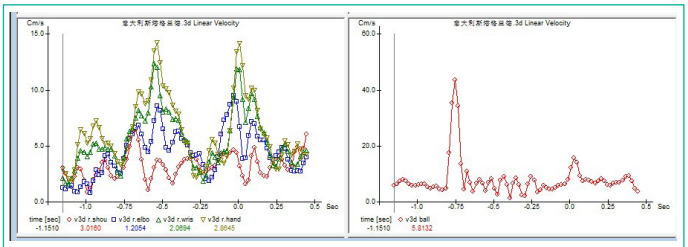

Figure 19: The variation of upper limb segment velocity and ball speed during Gesta Grande's hitting.

Figure 20: A schematic diagram of Gesta Grande's spiking stick figure.

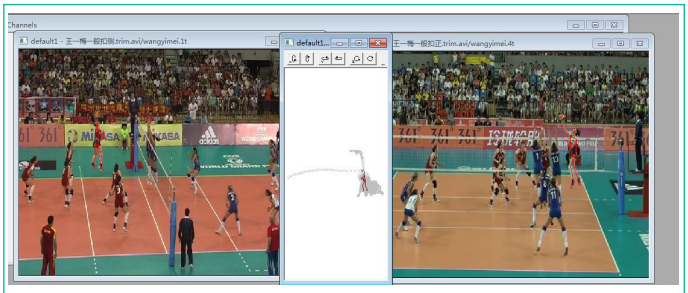

Figure 21: A compilation of multiple stick figures of Wang Yimei's spiking and the side and back video images of the moment of hitting the ball.

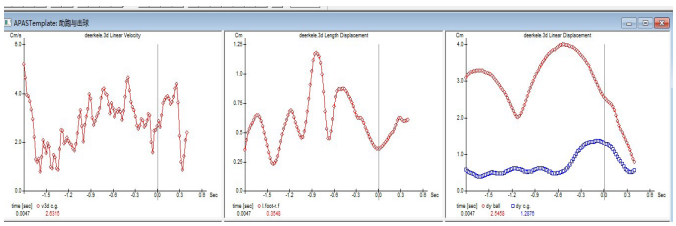

Figure 22: Graphical summary of Wang Yimei's assisted running speed, stride length, center of gravity height, and ball height changes.

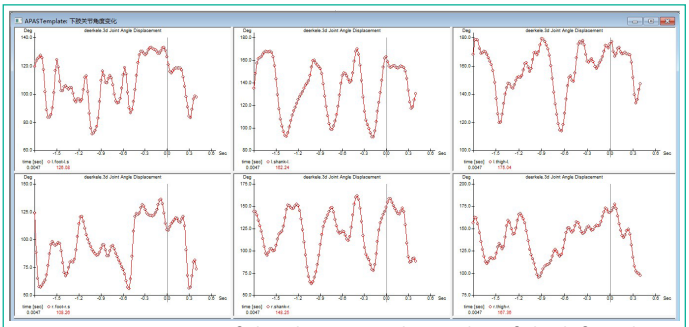

Figure 23: Summary of the changes in the angles of the left and right ankle, knee and hip joints of the lower limbs of Wang Yimei when she jumped from the spiking.

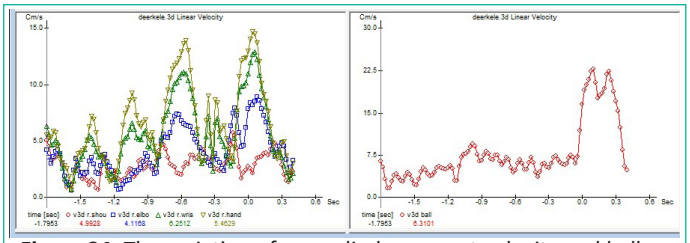

Figure 24: The variation of upper limb segment velocity and ball speed during Wang Yimei's hitting.

Figure 25: A schematic diagram of Wang Yimei's spiking stick figure.

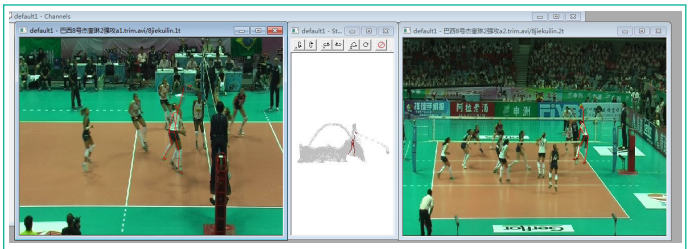

Figure 26: A compilation of multiple stick figures of Jacqueline's spiking and the side and back video images of the moment of hitting the ball.figure.

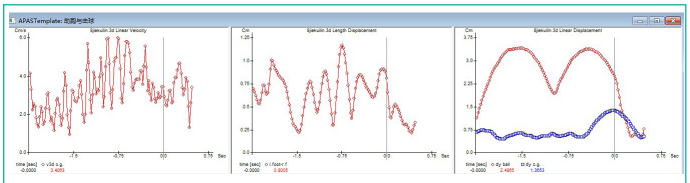

Figure 27: Graphical summary of the changes in assisted running speed, stride length, center of gravity height, and ball height during Jacqueline's spike.

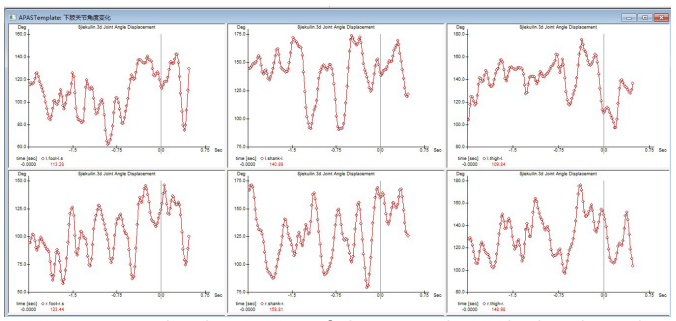

Figure 28: Graphical summary of changes in lower limb right and left ankle, knee and hip angles during Jacqueline's spike jump.

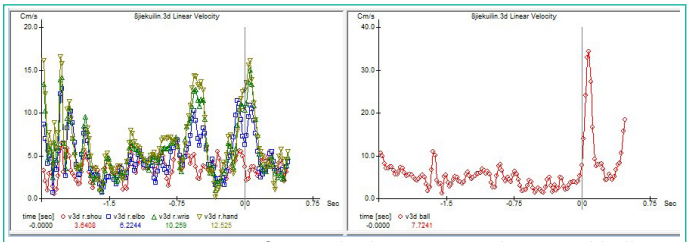

Figure 29: His variation of upper limb segment velocity and ball speed during Jacqueline's hitting.

Figure 30: A schematic diagram of Jacqueline's spiking stick figure.

Table 8 is a summary of the speed of each stage of excellent spikers in the world and their maximum ball speed, as well as the angle between their arm and torso during hitting. The research results show that the speed of the shoulder joint, elbow joint, and finger grip of the athletes during spiking all show an increasing trend. The speed range of the shoulder joint when spiking for the world's excellent female volleyball spikers is 2.6m/s to 5.6m/s, with an average of 3.77m/s; the speed range of the elbow joint is 7.4m/s to 10.3m/s, with an average of 7.57m/s; the speed range of the wrist joint is 10.2m/s to 15.3m/s, with an average of 11.88m/s; and the speed range of the finger grip is 11.8m/s to 18.5m/s, with an average of 14.27 m/s. The maximum ball speed after hitting is between 14.5m/s and 34.1m/s, with an average of 24.36m/s. The hitting point of the spike should be at the highest point of the jump and in front of the upper arm when it reaches its highest point. The angle between the arm and torso is approximately 164 degrees. [Huang Hansheng. Ball Sports-Volleyball [M]. Beijing: Higher Education Press, 2005:85.] From the research results, the range of the angle between the arm and torso is 133° to 159.7°, with an average of 150.40°, which is different from what is described in volleyball textbooks.

The model for the spike hitting phase of excellent female spikers in the world is as follows: the hitting height range of the spike is between 2.85m and 3.06m, with an average of 2.92m; the height of the center of gravity at the moment of hitting ranged from 1.29m to 1.75m, with an average of 1.63m; the maximum height of the center of gravity ranged from 1.29m to 1.75m, with an average of 1.64m; and the center of gravity velocity ranged from 2.60m/s to 4.7m/s, with an average of 3.33m/s. The maximum ball speed of hitting exceeds 25m/s, and a few athletes' maximum hitting speed exceeds 30m/s. The angle between the arm and the trunk during hitting is 150.40°.

Case Analysis and Research of the World's Best Female Volleyball Spikers' Spiking Techniques

Analysis of Huiruoqi's spiking technique: Hui Ruoqi, as the main athlete of Chinese women's volleyball team, has more comprehensive skills. The techniques of spiking, blocking and receiving and serving are more balanced. As the main offensive force of Chinese women's volleyball team, she is also the main ball handler. Although there is a certain gap between her absolute strength and foreign excellent spikers, she can make up for her lack of strength to a certain extent by virtue of her excellent moving speed and accurate judgment. Hui Ruoqi's snapping technique is characterized by: quicker assisted running, timely jumping, certain height in the air; fast hitting speed; good at close spike, sharp-angled spike; good power of wrist and other small muscle groups. The shortcomings are: the power of hitting the ball is small, and the ability of distance attack is poor; the use of waist and abdominal power is not obvious enough after rising in the air, i.e. the distance of displacement in the air is small after jumping; when she facing the blockers ,the variation of hitting techniques is not rich enough, and the combination of hitting and hanging is not reasonable; there is more room for improvement in the use of qucik-B, snap of wrist and other variation of hitting. 2012 London Olympic Games personal scoring statistics ranked ninth, including 236 spikes, scoring 84 points, blocking 42 times, scoring 8 points, serving 105 times, scoring 8 points, a total of 100 points; spike session, scoring 84 times, 39 times lost points, spike over 113 times, spike 236 times, scoring rate of 35.6%, spiking technology ranked 20th.

Hui Ruoqi in the vicinity of the player No. 4 , under the cover of the second spiker quick spike from close set, more fully prepared to receive the setter close set, choose a sharp-angled spike, the ball landing point for the court 3 meters inside the line. From the whole action process, although the running speed is not fast, but the jumping speed is fast, while hitting the ball more quickly and powerfully, the line selection is appropriate, when the Russian blockers move to form a collective block, quickly snap of wrist, complete the near net, small diagonal hitting, and thus avoid the opponent's blocking net. Using the advantages of fast self-bounce and accurate timing of the incoming ball to speed up the speed, rhythm and changes in the face of Russian players blocking, is undoubtedly an effective way for Hui Ruoqi to improve the efficiency of the spike. However, Hui Ruoqi should learn Saori Kimura in terms of technique, skill changes, and body control. As can be seen from Figure 2, at the moment of 0 point, that is, the moment of calibrated hitting two feet step width is the smallest; at the same time there is the center of gravity and ball height change graph can be seen, in the moment of the player hitting the ball, the player's center of gravity height is in the wave period. From Figure 3, it can be seen that the crest and trough of Hui's right hip change are wider than the angle change of the left hip, which may be related to the right turning action of her body. From Figure 4, it can be seen that the maximum ball speed of the player's spike does not appear at the moment of its hitting, but in the subsequent frames of the moment of hitting, which is because there is a certain acceleration phase after the ball is hit.

Tom Logan, an American athlete with Chinese ancestry, has conquered the volleyball world since she joined the US women's volleyball team in 2000, with her sweet appearance and solid technical skills. She has switched back and forth between indoor and beach volleyball, played in the Italian, Swiss, Spanish, Russian, Japanese, Chinese, and Turkish leagues, and has been a key member of the Olympic team for four times. Her comprehensive skills, balanced offense and defense, excellent sense of time and space, and strong adaptability have made her a well-respected athlete. In the 2012 Olympics, Tom Logan scored 61 points from spikes, 10 points from blocks, and 4 points from serves, for a total of 75 points, ranking 20th in the scoring list. Among them, she scored 61 points from spikes, lost 19 points, with a spike success rate of 34%, ranking 14th in spike technique.

Tom Logan is positioned near the player No.4 attacking line. He starts the spiking action before the ball arrives in the setter's hands. After the setter sends out a high ball, Logan quickly takes a cross-step and a side-step to approach the ball, jumps rapidly when he is about 2 meters away from the net, and slightly turns his body to the right to form a good arch. He performs a powerful sharp-angled spike, tightly wrapping his palm around the ball. As the hitting point is far away from the net, it makes it difficult for Chinese blockers to fight. Tom's whole dunking action is consistent, smooth and coordinated, while the jumping height is high and the hand movement changes while using the advantage of stagnation. Therefore, Tom's good waist and abdominal strength, and the control and adjustment of the body in the air are worth learning from Chinese female volleyball players, and Chinese female volleyball players should strengthen the muscle practice of core muscle groups, rather than emphasizing the practice of lower limb muscle strength. From Figure 7, we can see that the height of the center of gravity and the height of the ball is at the peak of the wave at the moment of hitting the ball, and it is a common feature of the spikers to strive to hit the ball in the area of the maximum height of the center of gravity. Therefore, a good sense of space, speed and position are necessary conditions for a good spiker. From Figure 9, it can be seen that there are three obvious peaks in the change of speed of each link of the upper limb of the athlete's batting, which coincides with the three characteristics of the athlete's arm's backward lead, forward swing and batting, while the speed of each link of the athlete's upper limb reaches the maximum at the 0 point, i.e. the moment of batting. From the graph of ball speed change, it can be seen that before the player hit the ball at 0:00, the overall ball speed remained relatively stable, which is undoubtedly also beneficial to the spiker to implement effective attacks

Analysis of Saori Kimura's Spiking Technique: Since the 2003 Women's Volleyball World Cup, Saori Kimura has gained widespread attention for her comprehensive and technically sound approach. Her lack of obvious technical weaknesses allows her to excel in various positions on the volleyball court, as a spiker or ssecond spiker, libero, or setter. In addition, her attractive appearance has earned her the nickname of "versatile beauty." While inheriting the excellent defensive techniques of Japanese female volleyball players, Kimura's height of 185 cm fully showcases the agility, speed, and variability of Asian players.

At the 2010 Women's Volleyball World Championship, Kimura attempted 505 spikes, scoring 208 points with a spike success rate of 41.19%. With 13 points from blocks and 19 points from serves, her total score was 240 points, ranking her second in personal scoring rankings. Her spike scoring even surpassed that of Ksenia Gamova from Russia, who had 188 points. She played a critical role in Japan's historic third-place finish. At the 2011 Women's Volleyball World Cup, Kimura attempted 360 spikes, scoring 151 points, making 40 unforced errors and 169 unsuccessful attempts, resulting in a spike success rate of

41.94%. She ranked fifth in personal spike technique rankings, contributing to Japan's fourth-place finish.

At the 2012 London Olympics, Kimura attempted 339 spikes, scoring 133 points, making 46 unforced errors, and recording 160 general attempts, resulting in a spike success rate of 39.2%. Her spike technique ranked twelfth and was higher than Hu Ruoqi from China by eight places.

Saori Kimura in the No. 4 position after the 3-meter line, in the ball has not reached the setter, has begun to move, choose the direction and timing of the upper step, after the ball to the setter, quickly take a large step and a small step up, in the distance from the center line near the 2.5m jump quickly, the body has a strong forward impulse, stretching the arm quickly and vigorously hit the ball, hitting the ball direction aimed at the opponent's blocker, coupled with changes in hand movements, causing the block out, The ball is aimed at the opponent's blocker. Quick start, quick jump, strong belly and back, distance attack, clear line and rich variations are undoubtedly Kimura's excellent attacking methods against the block. Creating a spike off the block is undoubtedly one of the attacking techniques that technical spikers must master. Chinese Hui Ruoqi should learn and use more of these technical characteristics to enrich the variation of hitting techniques and line changes. From Figure 12, we can see that there is an obvious rising curve after the ball is hit and falling after experiencing a wave, which is greatly related to the good passing technique of its setter, thus making the ball path smooth and stable, and at the same time, after the ball is hit at the moment of 0, the height of the ball has a rising trend instead, which is because Kimura faces the blocker when hitting the ball This is because Kimura intentionally hit the ball upwards to create block out. This is certainly worth learning from Chinese players. From Figure 13, we can see that Kimura's left and right hip joints do not change much from front to back at the moment of hitting, especially the right hip joint, which is related to Kimura's long forward movement and no diagonal hitting action. From Figure 14, it can be seen that the ball speed rapidly becomes larger to the maximum after the 0 moment, which also indicates that Kimura's hitting speed is faster.

Analysis of georgina pinedo's spiking technique: Georgina Pinedo, as an Argentine, has been playing in the Italian Women's Volleyball League for many years and has become a naturalized player for Italy. In the 2011 Women's Volleyball World Cup, she led the Italian Women's Volleyball team to win the World Cup championship. As an athlete from South America, Pinedo's athletic talent is fully reflected in her height, strength, and good jumping ability. Pinedo has a comprehensive set of skills and is one of the world's most outstanding spikers. Her attacking ability is excellent, and she is good at spiking off the block and back-row attacks. Her outstanding hang time and observation skills, as well as good explosive power, make her spiking technique highly efficient. Additionally, her specialties include drop shots and changing the trajectory of the ball. In the 2012 Olympics, Pinedo scored 67 points in spiking, 8 points in blocking, and 1 point in serving, ranking 19th in the individual scoring list. Among them, in the spiking attack section, she scored 67 times, made 22 errors, attempted 107 times, and her spiking success rate was 34.2%, ranking 16th in the BEST SPIKERS list.

Georgina Pinedo, at position 4, retreats after receiving frist pass from her teammate and chooses the right timing to take her step. She prepares to start moving backward once her teammate receives the pass. After the second pass, she assists in running, and although her running speed is not fast, her stride is large, and her body's center of gravity does not rise very high. She maintains the direction of her jump when hitting the ball, suddenly snapping of wrist to reduce the hitting force, causing the ball to hit the outside hand of the blocking player near the antenna and causing block out. When she has a certain height, she suddenly reduces the force, snap of wrist, and creates spike off the block while maintaining the characteristics of a powerful spike. Georgina's hitting rhythm changes, alternating between strong and weak, combining spikes and drop shots, and creating clear and precise trajectories, which are her characteristic techniques. Her clear mind, broad vision, good core strength, and hang time, good judgment of the players' positions on the court, understanding of the opponent's blocking deployment, and skillful hitting techniques are necessary for her excellent technical characteristics. It is recommended that Chinese spikers like Wang Yimei learn from Georgina Pinedo to enhance their ball sense, enrich their hitting movements, improve the rhythm of their hitting power, enhance their judgment and understanding on the court, and improve their ability to read the game, thereby improving their attacking efficiency.

Analysis of wang yimei's spiking technique: As a long-time key player and spiker for the Chinese women's volleyball team, Wang Yimei's main technical features are her strength and high hitting point. However, her lack of diverse hitting trajectories and limited variation in her hitting movements has become obstacles to further improving her attacking level. When facing tall blocker, her advantages in strength and height cannot be highlighted. In addition, in the Chinese women's volleyball team's emphasis on a fast and versatile system, Wang Yimei's lack of speed will undoubtedly magnify this deficiency, which is a key factor for her low spiking success rate and insufficient efficiency. In the 2010 World Championships, Wang Yimei spiked a total of 353 times, scored 141 points, and had a spiking success rate of 39.94%, ranking 21st in spiking technique. In the 2011 Women's Volleyball World Cup, Wang Yimei spiked 288 times, scored 112 points, and had a spiking success rate of 38.89%, ranking 14th in spiking technique. In the 2012 Olympics, Wang Yimei scored 52 points with 23 errors in 137 spiking attempts, resulting in a spiking success rate of 37.9% and ranking 18th in spiking technique.

Although her run-up speed is not very fast, her jump has a certain height. During the jump, her back arches significantly, and her left arm raises to drive her body upwards, while her right arm bends and extends backward, and her body turns sideways to the right. She hits the ball from a medium to far distance from the net, with a powerful cross spike. During the hitting action, her body twists to the left and front, and the hit is strong, with a cross spike. Her body falls about 1.5 meters away from the centerline, and her movement in the air is not very noticeable.

From a structural analysis of her movement, Wang Yimei has the characteristics of a world-class spiker, such as a high hitting point, great strength, and a large angle trajectory. However, her hitting trajectory is not diverse enough, her hitting movement variation is limited, her hitting rhythm is not obvious enough, and her movement speed is slow, which limits her further improvement.

Analysis of jacqueline's spiking technique: As a spiker for the Brazilian women's volleyball team, Jacqueline has a tall and beautiful physique, and comprehensive technical skills. Although her attacking strength is not extremely strong, her balance between attacking and defending and comprehensive technical characteristics makes her fully adaptable to the tacti-

cal needs of the Brazilian women's volleyball team. Meanwhile, her clear selection of hitting trajectory, fast movement speed, significant air displacement, strong abdominal strength, and quick hitting speed, combined with her flamboyant personality and unique game passion, have made her stand out in the world women's volleyball arena. In 2001, Jacqueline was first selected for the Brazilian women's volleyball national team. In 2006, she won the Grand Prix Finals championship and World Championship runner-up. In 2007, she won the World Cup runner-up. In 2008 and 2012, she won two Olympic championships. In the 2012 Olympic Games, she spiked a total of 189 times, scored 80 points, made 19 errors, and had 90 general hits, resulting in a spiking success rate of 42.3% and ranking 6th on the spiking technique leaderboard.

Jacqueline indirectly served the opponent in the court, frist pass in place, began to run, jumped near the three-meter line, jumped quickly, the back arch of the body in the air was extremely obvious, the right arm was fully drawn back with flexed elbow, while the body had an obvious forward rush, the player had already connected to the middle line after the stroke was completed. The ball was hit with sufficient force and clear line, avoiding the opponent's blocking and hitting the ball from the gap between the blocker and the antenna. Due to the great power of the ball, the ball quickly changed its line and went out of bounds after touching the opponent's defender. The power of Jacqueline's hit was evident from the "bang" sound of the ball touching the player. From Figure 4-28, it can be seen that Jacqueline's left and right hip angles change a lot before and after the moment of 0. The peaks and valleys are obvious, which are caused by the formation and completion of the back arch of the hip joints before and after the jumping and hitting of the ball. From Figure 4-29, it can be seen that the ball speed appears to rise in a nearly straight line at the moment of 0, i.e. after being hit, which also indicates that Jacqueline hits the ball with high speed and power. Jacqueline's hitting height is close to 2.9m and the maximum ball speed of the hitting ball exceeds 30m/s, which is relatively rare among female volleyball players.

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