

Digging Techniques of Elite Men's Volleyball Players in International Matches

国際試合におけるバレーボール一流男子選手のスパイクレシーブ技術に関する研究

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Abstract

The purpose of this study was to investigate the digging techniques of elite male volleyball players against spikes in volleyball. 34 occurrences of forearm digging motions in excellent receptions in 6 games (Argentina vs Cuba, Poland vs Iran, Serbia vs Japan, Iran vs Argentina, Cuba vs Serbia, and Poland vs Japan) from the 2011 Men's World Cup Volleyball were analyzed by the Direct Linear Transformation Method.

The results were as follows. First, in 477 occurrences of receiving (blockers did not touch the ball), receivers touched the ball 200 times, accounting for 42%. However, counter attacks (excellent receptions) occurred only 69 times, accounting for 14%. Second, 29 dig errors by liberos (24%) caused lost points, but that was lower than 93 dig errors (76%) by other players. Third, in 18 occurrences, the positions of liberos at receive impacts were located left-back. Finally, in 18 occurrences, up-down hip joint movements of liberos became higher close to the moment of spike hit for almost all of the trials. In addition, liberos made a pre-jump movement prior to hits in almost all the trials.

key words: volleyball, dig, elite male player, libero

I . Introduction

1. Background and Purpose of this Research

In top-level men's volleyball matches, the speed of a volleyball spike travels so fast that it exceeds 100km (27.8 m/s) (Hashihara, Yoshida & Yoshida, 2009; Yoshida, Nishi, Fukuda, Endo & Hashihara, 2015a; Yoshida, Nishi, Fukuda, Endo & Hashihara., 2015b). Even if a player is in the ready position, it should be hard to touch the ball because the player cannot react to the ball. Toyoda and Yamaguchi (1966) point out that it should be theoretically impossible to receive the ball because it takes over 0.33 sec for a player to react and the ball arrives at a speed of 0.33 sec without considering air resistance. Also, the ball is traveling at the speed of 100 km/h when it reaches the back of the volleyball court (9 meters away from the net). Even though the receiver might luckily contact the ball, it is not easy to return the ball to the target area on his own court at those speeds. Therefore, a spike receive is a difficult tactical skill, as 'the player has to play to the very limits of human reflexes if the spiker spikes the ball as hard as he or she can' (Japan Volleyball Association, 1988, p.50). However, receiving a spike is a significant defensive skill that is necessary for a team to win.

Unless the player can receive a spike ball deflected off the block and get a point by changing from

defense to offense, the opposing team will win the point.

For practical coaching sessions, the players are instructed to stop before a player spikes the ball and to take a position in the direction of the ball and to maintain the ready posture. Thus, most of the movement before the spike receive actually takes place before the ball is attacked (Liskevych & Neville, 1997, p.187; Selinger & Ackermann, 1986, p.207). "Players should stop, weight forward, just prior to the attack" (Neville, 2004, p.71), and the receiver stops before the player spikes the ball (Kaneko, 2001, p.7; Koito, 2001, p.3). These coaching tactics are so prevalent that coaching tactics for ready posture and timing are commonly used.

As mentioned above, positioning and ready posture for a spike receive are very important defensive skills, whose effectiveness requires the defending team to move as soon as they determine the direction of the ball tossed by a setter, since in recent top-level matches 4 players have only approximately 1 second or less to take offensive action after the releasing toss (Hashihara et al., 2009). That time restriction makes it difficult for the blockers on the defending team in the front row to block the spiked ball, and moreover makes it more difficult for the receivers in the back to perform movement tasks since they have to react to the spiker and the blockers on their own team.

On the other hand, previous research on spike receives such as study on ready posture and response time targeted at university students (Kitamura, Matsushima & Yamaji, 1985; Shimoshikiryo & Sunamoto, 1980; Toyoda & Furusawa, 1982), and defending positions targeted at elite teams (Katsumoto, 1989; Sagano, Jin, Hashihara & Nishimura, 1998) and amount of movements and timing for ready posture (Yoshida, 2011; Yoshida & Yoshida, 2001) agree on the significance of the ready posture and the timing recognized just before contacting the ball. However, except for the study by Sagano et al. (1998), none of them have examined how the players should move to where the ball will be hit and take a position. In addition, no research quantitatively evaluated defenses against 4-player-offences even though they are a major strategy in top-level of men's volleyball matches.

Sagano et al. (1998) recorded the match between Italy and Japan (Italy won the championship and Japan was fifth) on video at the 1995 FIVB Volleyball Men's World Championship at Hiroshima Green Arena, in Hiroshima, on 23rd November, 1995, and examined the defense system against 4 player-based combination attacks from the left side, by using two-dimensional DLT. The analysis shows that there were great variations among Japanese players, in the defensive positions of the back-row players at the very moment of getting in a ready position for a spike receive compared with the Italian players. According to this analysis, variations in positioning among back-row players of the Japanese team were large, while Italian team players on the whole went more towards the back of the court at the spike impacts than to the ready posture: the left back-row and the middle back players moved more to the left, and the right back-row players moved more to the right. This analysis, however, is a case study, so it cannot be said that it explains the general characteristics of top level players' receive moments.

Thus, even though the coaching books for spike receiving techniques explain how to move, there have not been so many quantitative investigations on spike receiving movements, nor has the relation

between moving achievements and moving processes in receiving spikes been examined.

As mentioned above, there is no time for a receiver to move after a spiker hits the ball because of its high speed. Needless to say, there is less time because offense moves are so quick in elite matches. So, hand movements are more significant because they enable a player to manipulate the ball by contacting the ball on his or her platform after moving towards the ball and maintaining a ready posture before a spiker attacks. Thus, this research focuses on upper and lower limb movements in the sequence of a spike receive when a player moves towards the ball for a ready posture, examines top level players' movements to the spike receive position and control of the ball, and aims to provide quantitative results to exemplify spike receiving skills for players to improve.

2. An Approach to Research

Tawa (1972, p.403) presents a methodology to accurately analyze performing movements, especially the establishment of performing techniques, and points out that it is significant to recognize and explain the fundamental principles of dynamics, physiology, anatomy, and morphology so that the most congruent and economical methodology can be sorted out from these performing movements. Therefore, in this research, the direct linear transformation method (DLT) is used in order to sort out the motions generally applicable to elite players by focusing on successful dig-receptions of elite players in the international competitions, in which the best defensive techniques are exhibited and analyzing multiple trials of the players and those among players as well. Finally, this research clarifies how elite players rationally perform a dig by analyzing the collected data and the common movements of elite players.

II . Methods

1. Target Analysis

The analysis targets receiving movements against spikes in the six matches between Argentina (ARG) and Cuba (CUB), Poland (POL) and Iran (IRI), Serbia (SRB) and Japan (JPN), IRI and ARG, CUB and SRB, and JPN and POL at the FIVB Volleyball Men's World Championship, which was held in Osaka on the 24th and 25th November, 2011.

2. Target Trials

All of the matches recorded on video were evaluated by an internationally qualified coach. This research sorts out the total number of 34 receiving motions performed (18 trials for liberos and 16 trials for other players). They meet all of the following conditions for receiving movements against spike impacts in international male competitions: 1) receiving motions against the spike impacts without blockers taking hits, 2) receiving motions return to the team court (9m × 9m), and 3) receiving motions were underhand.

3. Recording the Matches

Three charge-coupled device (CCD) color video cameras (Victor Company of Japan Ltd.: TK-C1381) with a digital video camera connected to each CCD camera by an S-video cable were used to record the matches. Cameras were fixed on the floor in the aisle on the second floor to focus on the target area of the court with one camera facing from behind the end line and the other two cameras facing opposite sidelines of the court. The shooting range of cameras was set up to capture 9 meters, the length of the end line of the court, and all plays from the beginning to the end were recorded at 30 FPS (frames per second) and a shutter speed of 1/500 sec. Calibration points were recorded before the matches began. In addition to calibration poles located at 8 points of the volleyball court (Figure 1), the intersection between the white belt and the antenna and the intersection between the center line and the sideline of the volleyball court were used as control points for the DLT method (Walton, 1979).

4. Data Analysis

For this investigation, images recorded by the three cameras were captured by Virtual Dub, a video editing software, into a personal computer, and after deinterlacing, every image of the trials was made by double-processing from 30 FPS to 60 FPS and by decompressing the image files to transport them into the analysis software. The processed data was manually digitalized by ImageJ software, a source image processing program, to obtain two dimensional coordinates. Digitized data were synchronized using set-dig impact frame. Then, after calculating three dimensional coordinates by the DLT method (Walton, 1979), the author analyzed the data using his own customized analysis program created in Visual Basic. The standard error of measurement between the estimated value and the measured value, in calibrators in the three dimensional coordinates, are 0.006m~0.008m for the X direction (the sideline), 0.008m~0.018m for the Y direction (the center line) and 0.006m~0.008m for the Z direction (the vertical direction).

5. Measurement and Calculation Methods

(1) Analysis of Receiving Skills

A total of 477 defensive actions out of 994 hard offensive hits where balls were received and were not touched by blockers were analyzed for receiving skills and divided into digs by liberos and those by other players.

Receiving skills are defined and classified into the following categories: successful spikes that landed directly onto the court without touching blockers or receivers (SPK success), spike errors (SPK error), successful digs that returned the ball to the opponent's team court (reception success of dig), digs returning the ball directly to the opponent's court so that the rally could continue (return dig), and dig errors in which the ball could not be returned to the opponent's court (lost points by dig error).

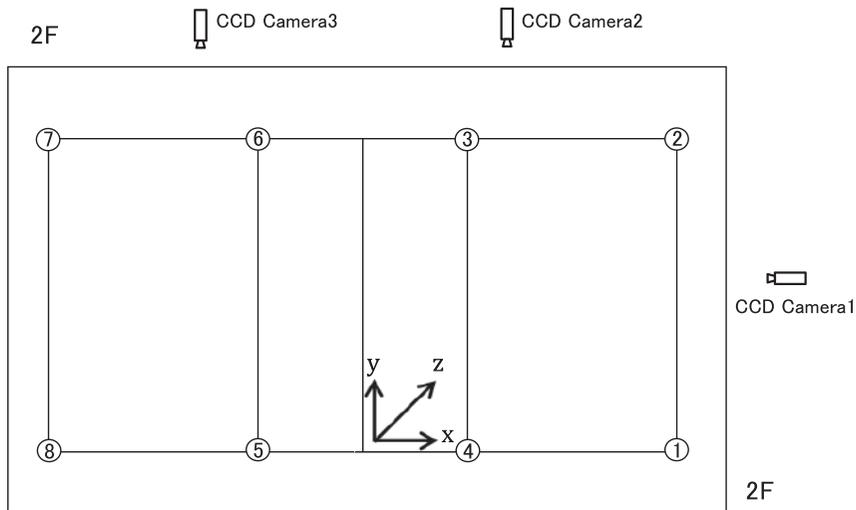


Figure 1 Cameras and the Calibrator position

(2) Performance of Players

① Offensive Action durations

Offensive action durations were calculated by multiplying the number of frames from setting releases to spike hits by sampling time. Toss releases were set at the time the balls were released from the setter.

② Returning Dig Positions

Positions for receiving balls were set as the vertex positions of the ball trajectories after receiving and approximate formulas were calculated by using time and position data of the ball in the three frames right after receive impacts. The horizontal component approximates a linear equation of time and the vertical component approximates a quadratic equation.

(3) Positions of Receivers

To examine where the receivers took positions on the court at set impacts and receive impacts, three dimensional positions were determined with the origin at the intersection of the left sideline of the team court and the central line and the midpoint between the left and right hip joints of the receivers.

(4) Range of Receive Impacts

To examine how wide receivers took positions for underhand reception at receive impacts, a coordinate transformation of vectors from the left shoulder to the right shoulder of the receivers was performed and unified. The relative position was determined with the central coordinate of the ball with the origin at the midpoint between the left shoulder's joint center and the right shoulder's joint center. In addition, the angles were made at receive impacts between the X axis (for-backward direction) and the vector starting from the midpoint (the origin) between the left and right shoulders' of the receivers and

their movement to the balls.

(5) Steps of Receivers

To examine the timing of receivers' steps before and after spikers' hits, a spike hit was set to zero time and the times were calculated when the receivers' feet were off the floor (at Pr1 and Pre2 off the floor) and on the floor (at Pr1 and Pre2 on the floor) before and after the hits.

(6) Hip Joints of Receivers

To examine ready positions of receivers' hip joints before and after spikers' hits, a spike hit was set to zero time and the vertical distances were calculated between the floor level and the midpoints between the right and left hip joints from spikers' second step on the floor at takeoffs to receive impacts.

(7) Defensive Range of Receivers

To examine how far the receivers could move to receive the ball as soon as the receivers took positions for receive impacts, three dimensional positions of the midpoint between the right and left hip joints of the receivers were determined just before the receivers took position for receive impacts; that is, when the receivers took the second step on the floor at pre jumps prior to receiving impacts and the coordinate transformation of the vector going from the left hip to the right hip of the receivers were performed and unified. Finally, the relative positions to the central coordinate of the balls at receive impacts with midpoint coordinates between the right and left hip joints as the origin were calculated.

III. Results and Discussion

1. Evaluation of Receiving Skills

Table 1 shows the evaluation of receiving skills. Among 27 sets of analyzed games, the total number of offensive actions done by hard hits was 994, including 665 after receptions and 329 during rallies. Of those offensive actions, the number of defensive actions against the ball without touching the block was 477, which is the total number of defensive actions. Of those 477 defensive actions, the number of successful spikes without being received was 224 (successful spikes), the number of unsuccessful spikes was 53 (spike errors), the number of reception successful digs was 69 (reception success of dig), the number of digs returning the ball directly to the opponent's court so that the rally could continue was 9 (return digs), and the number of digs with one touch blocking which could not return the ball to the opponent's court because the rally could not continue was 122 (lost points by dig error). Of the number of 69 successful digs, there were 49 times when the ball was kept in the team's court. Of those 49, 34 trials by forearm dig (except for single hand dig) were analyzed in this research.

The number of successful spikes that did not touch blockers or receivers in the opponent's court was 224 (successful spikes), accounting for 47 % of the defensive actions against hard hits (477). Also, 122

Table 1 Skill evaluation of spike receives

the total number of offensive actions	the total number of defensive actions	breakdown of defensive actions							
		success of SPK	error of SPK	reception success of dig		return dig		lost points by dig error	
				Liberos	Others	Liberos	Others	Liberos	Others
994	477	224	53	30(26)	39(23)	0	9	29	93

※ () refers to the number of digs returning to the team's court

the total number of offensive actions: the number of offensive actions done by hard hit

the total number of defensive actions: the number of defensive actions against balls deflected off blockings, which means the total number of reception successes of SPK, SPK errors, digs.

success of SPK: the number of successful spikes which are touched but unable to be kept in play

error of SPK: the number of unsuccessful spikes out of court

reception success of dig: the number of successful digs returning the ball to the team court without one touch blocking

return dig: the number of digs returning the ball directly to the opponent's court and the rally continues

lost points by dig error: the number of digs without one touch blocking which cannot return the ball to the opponent's court. The rally cannot continue.

Others: other players except for liberos

rallies ended when a spiked ball was not touched by blockers and could not be returned to the opponent's court by receivers (lost points by dig error), accounting for 26 %. Thus, successful digs accounted for only 14 % of the total suggesting that it is difficult for top level-players to receive balls at high speed.

Examining lost points by dig errors, lost points by players except for liberos was 93 (76 %) which means that more lost points were caused by other players than by liberos. Examining return digs, there were no trials in which the liberos returned a ball directly to the opponent's court. This result suggests that the liberos' ball control skills are better than other players' skills.

2. Characteristics of Trials of Analyzed Games

Table 2 identifies characteristics of the trials during the analyzed games, and Table 3 illustrates characteristics of liberos (FIVB, 2011). The numbers 1-18 represent liberos, and numbers 19-34 represent other players.

As for offensive time from toss release to spike hit, quick attacks, which had the shortest offensive time, ranged from 0.283 sec to 0.433 sec with 0.361 sec as the average ($SD = 0.055$), while it was 0.683 sec (trial 28) for pipe attacks. Side attacks done as combination attacks ranged from 0.783 sec to 1.233 sec with 0.990 sec as the average ($SD = 0.146$), while side attacks performed by out-of-system(s) ranged from 1.217 sec to 2.067 sec with 1.491 sec as the average ($SD = 0.290$).

The time from a spiker's takeoff to spike hit was 0.374 sec on average ($SD=0.056$), the time from the forearm swing to spike hit was 0.203 sec on average ($SD=0.031$), and the time from spike hit to receive impact was 0.376 sec on average ($SD=0.055$).

For offensive time, 0.399 sec on average for quick attacks, 1.025 sec on average for left side attacks, and 0.885 sec on average for right side attacks by the Brazilian men's team have been reported (Nishi,

Table 2 Characteristics of trials

Number of trial	name	team	types of offensive actions	duration of offensive actions (sec)	takeoff - hits (sec)	upper arm swing - hits (sec)	hits - diggs (sec)	number of blockers	angle (deg)	notes
1	Rosic Nikola	SRB	L	1.067	0.433	0.200	0.400	2	25	4-attackers
2	Gutierrez Torna Keibel	CUB	L	1.233	0.283	0.167	0.400	1	17	3-attackers
3	Rosic Nikola	SRB	L	1.250	0.417	0.183	0.333	2	32	out-of-system
4	Gutierrez Torna Keibel	CUB	A	0.383	0.367	0.200	0.317	1	46	4-attackers
5	Rosic Nikola	SRB	R	0.917	0.367	0.183	0.283	1	27	4-attackers
6	Gutierrez Torna Keibel	CUB	L	0.783	0.400	0.233	0.350	1	26	4-attackers
7	González Alexis	ARG	L	1.283	0.333	0.183	0.400	2	32	out-of-system
8	Hossein Ali	IRI	L	1.217	0.300	0.200	0.400	2	17	out-of-system
9	Hossein Ali	IRI	RB	1.200	0.550	0.233	0.367	2	18	4-attackers
10	Hossein Ali	IRI	RB	1.500	0.400	0.217	0.350	2	12	out-of-system
11	Rosic Nikola	SRB	A	0.283	0.367	0.150	0.317	1	22	4-attackers
12	Nagano Takeshi	JPN	B	0.350	0.400	0.183	0.283	1	59	4-attackers
13	Nagano Takeshi	JPN	RB	1.750	0.333	0.200	0.450	3	31	out-of-system
14	Nagano Takeshi	JPN	L	1.300	0.400	0.217	0.400	2	13	out-of-system
15	Nagano Takeshi	JPN	RB	1.167	0.317	0.183	0.350	1	27	3-attackers
16	González Alexis	ARG	L	0.900	0.433	0.183	0.450	2	14	4-attackers
17	Hossein Ali	IRI	R	1.350	0.350	0.200	0.300	1	17	out-of-system
18	Gutierrez Torna Keibel	CUB	A	0.433	0.367	0.250	0.350	1	26	4-attackers
19	Leon Venero Wilfredo	CUB	L	1.017	0.300	0.200	0.467	2	41	4-attackers
20	Hernandez Ramos Fernando	CUB	RB	2.067	0.367	0.200	0.450	1	15	out-of-system
21	Zarini Hamzeh	IRI	L	0.817	0.333	0.217	0.433	2	39	4-attackers
22	Quiroga Rodrigo	ARG	RB	0.967	0.350	0.200	0.350	1	49	4-attackers
23	Crer Pablo	ARG	L	0.783	0.333	0.183	0.383	1	25	4-attackers
24	Conte Facundo	ARG	L	0.817	0.383	0.217	0.367	1	24	4-attackers
25	Miljkovic Ivan	SRB	RB	1.117	0.383	0.200	0.467	2	35	4-attackers
26	Miljkovic Ivan	SRB	L	0.983	0.400	0.200	0.350	2	38	3-attackers
27	Miljkovic Ivan	SRB	RB	1.700	0.467	0.250	0.450	3	21	out-of-system
28	Miljkovic Ivan	SRB	P	0.683	0.317	0.183	0.317	2	25	4-attackers
29	Abe Yuta	JPN	L	1.117	0.300	0.167	0.367	1	26	4-attackers
30	Kamalvand Arash	IRI	A	0.400	0.467	0.317	0.367	0	24	4-attackers
31	Fayazi Damnabi Pourya	IRI	A	0.317	0.350	0.250	0.333	0	22	4-attackers
32	Quiroga Rodrigo	ARG	RB	1.033	0.350	0.183	0.467	1	19	3-attackers
33	Solé Sebastian	ARG	L	1.033	0.417	0.183	0.417	2	29	4-attackers
34	Conte Facundo	ARG	RB	1.067	0.383	0.200	0.317	2	51	4-attackers
		Mean			0.374	0.203	0.376		28	
		SD			0.056	0.031	0.055		11	

number of trial: numbers 1-18 represent liberos, and numbers 19-34 represent other players.

team: SRB stands for Serbia, CUB for Cuba, ARG for Argentina, IRI for Iran, and JPN for Japan.

types of offensive actions: L stands offensive actions from the left, and R for ones from the right.

RB stands for back attacks from the right side, P for pipes, A for A quicks and B for B quicks.

duration of offensive actions: the time between ball releases from the setter to a spike hit.

takeoff - hits: the time between a spiker's take off from the floor and a spike hit.

upper arm swing - hits: the time between a spiker's upper arm swing and a spike hit.

hits - diggs: the time between a spiker's hit and receive impact.

number of blockers: the number of blockers. Players were counted as blockers if the tips of their fingers extended over the white belt of the net.

angles: angles formed between the X axis (front-back direction) and the following vector of the ball pointing from the midpoint (or the origin) between the right and left shoulder joints

Table 3 Characteristics of liberos

name	team	height (m)	SJ (m)	BJ (m)	Excel lents	Faults	In play	TA	AV	rank ing
Rosic Nikola	SRB	1.92	3.28	3.15	204	68	108	380	4.74	4
Gutierrez Torna Keibel	CUB	1.78	3.05	2.95	186	69	116	371	4.23	6
González Alexis	ARG	1.84	3.21	3.00	169	50	116	335	4.02	7
Nagano Takeshi	JPN	1.76	3.10	3.00	157	44	98	299	3.93	8
Hossein Ali	IRI	1.80	3.00	2.90	39	18	33	90	0.95	15
	Mean	1.82	3.13	3.00						
	SD	0.06	0.12	0.09						

SJ: maximum jump height by spike jump

BJ: maximum jump height by block jump

Excellents: number of excellent receptions in the liberos' trials (receptions, digs and sets)

Faults: number of trials resulting in lost points.

In-play: not included in "Excellents" mentioned above, the total number of rallies avoiding losing points

TA: the total number of attempts (Excellents + Faults + In play)

AV: average number of successful trials per set (Excellents / set points)

ranking: ranking of best liberos at the 2011 FIVB Volleyball Men's World Cup

* quoted from the FIVB

<<http://www.fivb.org/EN/volleyball/competitions/WorldCup/2011/men/>>

Yoshida, Fukuda, Endo & Hashihara, 2012), and 0.376 sec on average for A quick by top level men's players, and 0.410 sec on average of B quick were reported by Jin (2000). Examined trials in this investigation exemplify receiving skills for balls hit at high speeds by examining receiving motions to these offenses because motion effects equivalent to the offensive times of top level players can be achieved.

3. Vertex Position of Received Balls

Figure 2 shows a top view with the apex of the ball trajectory made by receivers' receptions as the apex of received balls. The origin was at the intersection of the left sideline of the team court and the center line. ○ represents liberos' vertex positions for received balls, and ● for other players' vertex positions for received balls. + signifies ± 1 standard deviation from the mean.

The apex of received balls from the center line ranged from 1.48 m to 7.57 m and averaged 4.44 m (SD=1.45), and the position from the sideline ranged from 0.41 m to 8.10 m and averaged 4.27 m (SD=1.54). As a whole, although there was a large variation, these data show that receivers tried to return the ball as close to the center of the court as possible. On the other hand, returned balls by liberos went to two thirds of the court area from the left sideline probably because liberos played in the left back in all of the 18 examined trials.

4. Positions of Receivers at Receive Impacts

Figure 3 shows a top view of the midpoints between the right and left hip joints of the receivers during toss impacts of the setter (left) in combination attacks and receive impacts (right) for the receivers' positions. Figure 4 shows a top view of the midpoints between the right and left hip joints of the receivers during toss impacts of the setter (left) in out-of-system(s) attacks and receive impacts (right) for the receivers' positions. The origin was at the intersection of the left sideline of the team court

and the central line. ○● represent the back-left players' high midpoint of their hip-joints, △▲ the back-left setters' high midpoints of their hip-joints, and □■ the high midpoint of back-right players' hip-joints. ○△□ represents the positions of the players attacking from the left side, ○△□ the positions of the players attacking from the center (quick pipes), and ●▲■ the positions of the players attacking from the right side including the right back attacks.

Generally, the position of receivers in combination attacks (Figure 3) shows that players at left back moved from sideline to inside the court against left side attacks and center attacks while they moved diagonally backward left against right attacks. There was only one trail found in which players at left back were located near the center of the court at the toss impact of the setter. They could not go back to home positions right after the offensive attack of their team because the opponent's team successfully dug and returned to the setter. Although players at center back moved to the left against left side attacks, they hardly moved against center attacks and moved to the right against right side attacks. Players at right back moved diagonally backward right against left side attacks and moved slightly inward to the center from sideline against center attacks and right attacks.

Then, generally the positions of receivers during the attacks done by out-of-system(s) (Figure 4) show that players at left back moved from sideline to inside the court against left side attacks, but moved

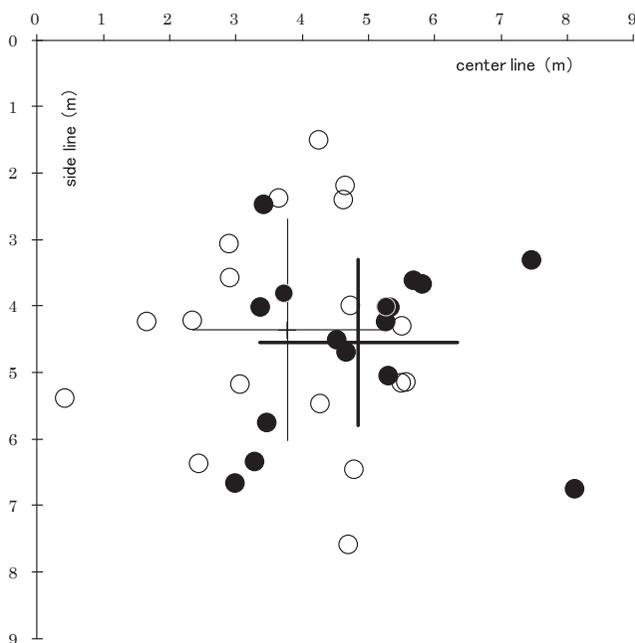


Figure 2 Vertex position of received balls (34trials)

The origin is at the intersection of the left sideline of the defending team and the central line. ○ stands for liberos' vertex positions of received balls, and ● for other players' vertex positions of received balls except for liberos. + signifies the mean ± 1 SD. Narrow + stands for liberos.

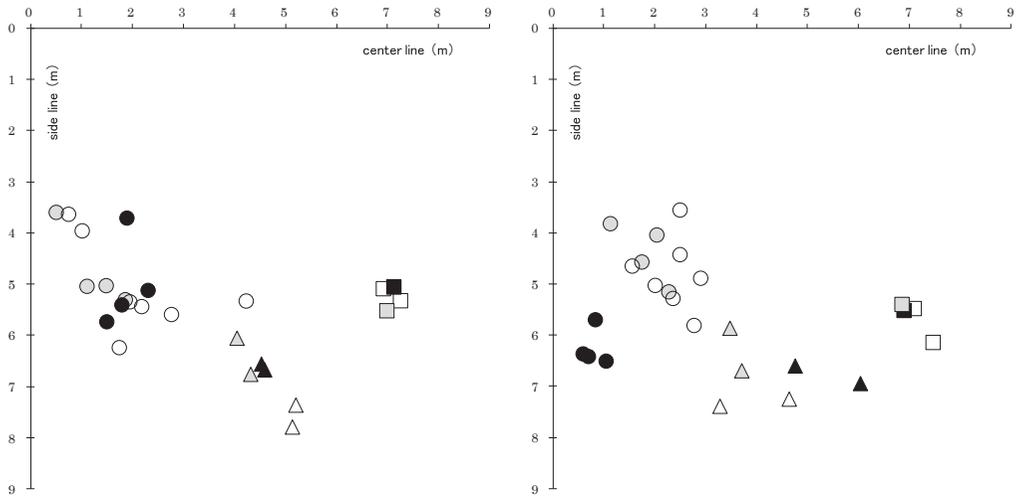


Figure 3 Positions of receivers in combination attacks (25trails)

The left figure shows the time of toss impacts, and the right one shows the time of receive impacts. The origin is at the intersection of the left sideline of the team court and the central line. ○● show back-left players' high midpoint of hip-joints, △▲ show middle back players' high midpoints of hip-joints, and □■ show high midpoint of back-right players' hip-joints. ○△ show the positions of the players attacking from the left side, ●▲ show the positions of the players attacking from the center (quick pipes), and ●▲■ show the positions of the players attacking from the right side, including the right back attacks.

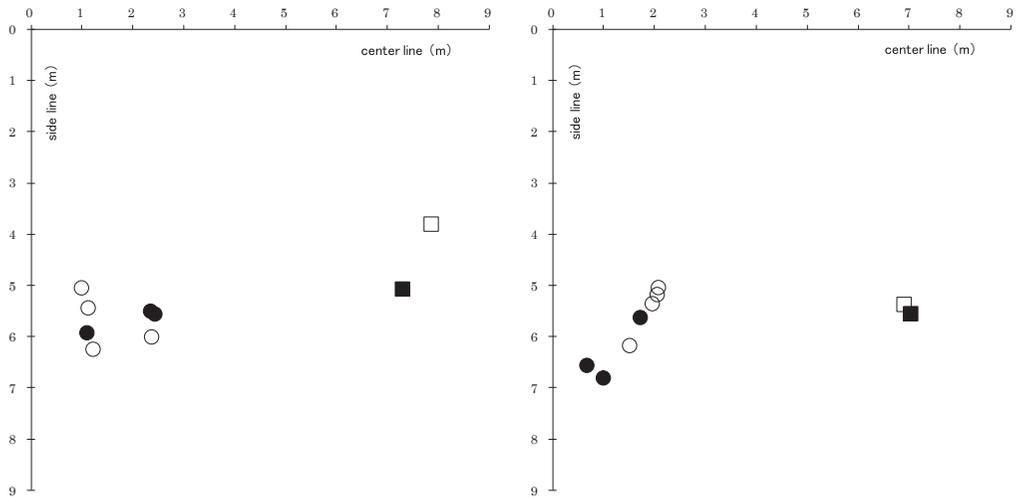


Figure 4 Positions of receivers in out-of-systems (9trails)

The left figure shows the time of toss impacts, and the right one shows the time of receive impacts. The origin is at the intersection of the left sideline of the team court and the central line. ○● show back-left players' high midpoint of hip-joints, □■ show back-right players' high midpoints of hip-joints. ○□ show the positions of the players attacking from the left side, and ●■ show the positions of the players attacking from the right side, including the right back attacks.

from inside the court to sideline, diagonally backward left, against right attacks. On the other hand, players at right back moved diagonally backward left against left side attacks, but hardly moved against right attacks.

For players at left back during receive impacts, players at left back on the whole took positions inside the court more during combination attacks than during attacks done by out-of-system(s), while players at right back didn't take positions inside the court. The same player in four of five trials received the balls in such a defensive style; he hardly moved once he took a position from the toss impact of the setter to the spiker's attacks.

5. Range of Receive Impacts

In order to examine the receiving range at receive impacts, Figures 5-1 and 5-2 show a top and a lateral view, respectively, in which a coordinate transformation of vectors from the left shoulder to the right shoulder of the receivers was made and unified. The relative position of the ball's origin was at the midpoint between the left shoulder joint center and the right shoulder joint center at the receive impacts. ○ represents liberos, and ● other players. + signifies ± 1 standard deviation from the mean. Narrow + represents liberos.

In each figure, the relative positions for the ball ranged from -0.28 m to 0.35 m in the right-leftward direction with 0.01 m as the average, from -0.62 m to -0.13 m in forward and backward direction with -0.42 m as the average, and from -0.31 m to -0.06 m in the vertical direction with -0.21 m as the average. These values indicate what part of a platform made by both forearms received the ball impacts and the ball impacts were near the vertical axis and were received within the range from approximately 0.4 m to 0.5 m in more than half of the trials.

The angles formed between the vector pointing from the midpoint (origin) of the center of the left and right shoulder joints to the ball position and X axis (in forward and backward direction) ranged from 12° to 59° and averaged 28° as a whole. For liberos' trials, the angles ranged from 12° to 59° and averaged 26°, and for other the angles ranged from 15° to 51° and averaged 30°. Thus, the liberos' angles were slightly wider. In trial 12, the angle was the widest (59 degrees angle) and it took 2.283 sec (Table 2) from spike hit to receive impact. The receiver ran short of time to make a flat platform by both arms, and could successfully receive only by forming a platform with both forearms, in which his elbow extension was incomplete. In the case that the angle was the closest to the midpoint (trial 17, 17 degree angle), it took 0.300 sec from spike after out-of-system(s) from the right side to receive impact (Table 2). During the receive, he formed a flat platform with both arms and received impact with both forearms.

Toyoda and Furusawa (1982) examined how 9 university male volleyball players reacted when they received a ball coming directly towards them and found that opening their hands to the side and extending forward was faster than putting their hands in front of their chest and it averaged 0.392 sec. On the other hand, Coleman and ColemaNeset (1994) asserted that players should take a receiving position or be set to in the state as close to a ready posture as possible because there was not enough time for

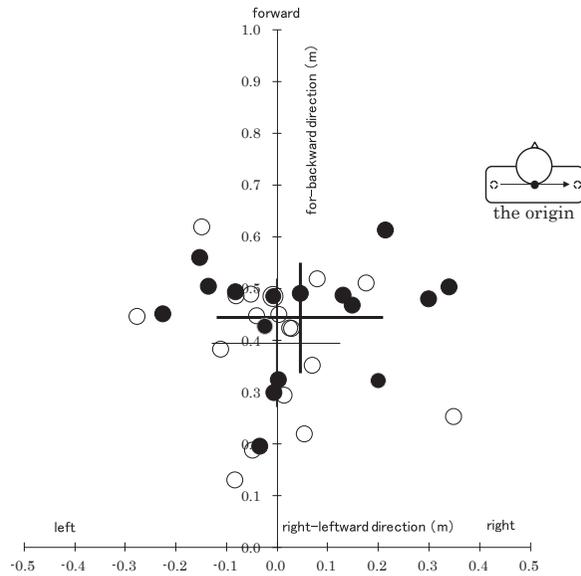


Figure 5 - 1 The range of receive impacts (after coordinate transformation)

a top view, in which a coordinate transformation of vectors from the left shoulder to the right shoulder of the receivers is performed and unified. The origin is at the midpoint between the left shoulder joint center and the right shoulder joint center. ○ stands for liberos, and ● for other players except for liberos. + signifies the mean ± 1 standard deviation. Narrow + stands for liberos.

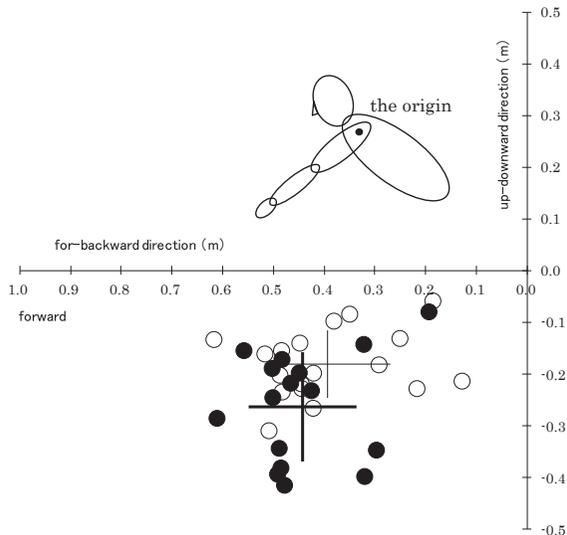


Figure 5 - 2 The range of receive impacts (after coordinate transformation)

a lateral view, in which a coordinate transformation of vectors from the left shoulder to the right shoulder of the receivers is performed and unified. The origin is at the midpoint between the left shoulder joint center and the right shoulder joint center. ○ stands for liberos, and ● for other players except for liberos. + signifies the mean ± 1 standard deviation. Narrow + stands for liberos.

players to put both arms together. Considering the average time from hit to receive in this investigation was 0.376 sec (SD=0.055), and the shortest was 0.238 sec (trial 5) for top level men's teams there were many situations in which players have no time to put both hands low with elbows extended, and form a flat platform with both arms; therefore, it might be better for players to hold their hands low in front of them rather than to extend them forward, and form a flat platform by extending their elbows right after the hits.

6. Up-Down Hip Joint Movements of Receivers or Steps

Figures 6 and 7 illustrate up-down hip joint movements of liberos and other receivers, respectively, and vertical distance from the floor to the midpoint between the left and the right hip joints. Zero time shows when a spiker attacks. ○ represents the takeoff at the first and second steps and ● represents the landing at the first and second steps, and △ represents the beginning of a spiker's upper arm swing. Table 4 shows up-down hip joint movements and Table 5 shows step time. The numbers from 1 to 18 show trials of liberos, and the numbers from 19 to 34 for trials of other players.

Examining up-down hip joint movements of liberos (Figure 6), regardless of the offense actions, their up-down hip joints became higher close to the moment of spike hit for almost all of the trials, and then, ① they became lower until receive impacts, ② they became flat right before receive impacts, ③ after the second step on floor contact, up-down hip joint movements became higher before received impacts. For the three trials in which up-down hip joint movements became higher after hits before received impacts, the players had to make their hip joints high by extending their knees, so that they could put their platforms up because the balls were hit around the receivers' chests.

Liberos' first steps of pre jump off the floor were recognized prior to spikes (zero time) in 16 out of 18 trials (Table 5). In 17 out of 18 trials, the first and second steps of pre jump on the floor were recognized after spikes. These data show that in almost all the trials receivers made a pre jump movement prior to hits. Movement time of pre jump (Pr time) ranged from 0.083 sec to 0.383 sec and averaged 0.217 sec (SD=0.085).

On the other hand, looking at up-down hip joint movements of other players, it was found that in most of trials, the hip joint movements became the highest right after hits, even though the timing of becoming higher slightly differed. However, in 4 trials (trials 25, 26, 27 and 28: trials by the same Serbian players), there were no up-down hip joint movements around spiker hits found, and from the moment the spiker's toe left the ground (toe-off) to the point at which the spikers hit, up-down hip joint movements became moderately lower.

As for steps, in 8 out of 16 trials the first steps of pre jump off the floor were recognized prior to spikes (zero time), and in 4 of the 8 trials (trials 25, 26, 27 and 28), pre jump movements were not found.

For pre jump movements, Tomosue (1997, p.25) pointed out that "the split step occurs when the receiver makes a preparatory jump move at the time of service. It was found that at the time of service impact with the ball, it was also the highest point in the jump." Nishi, Yoshida and Hashihara (2016)

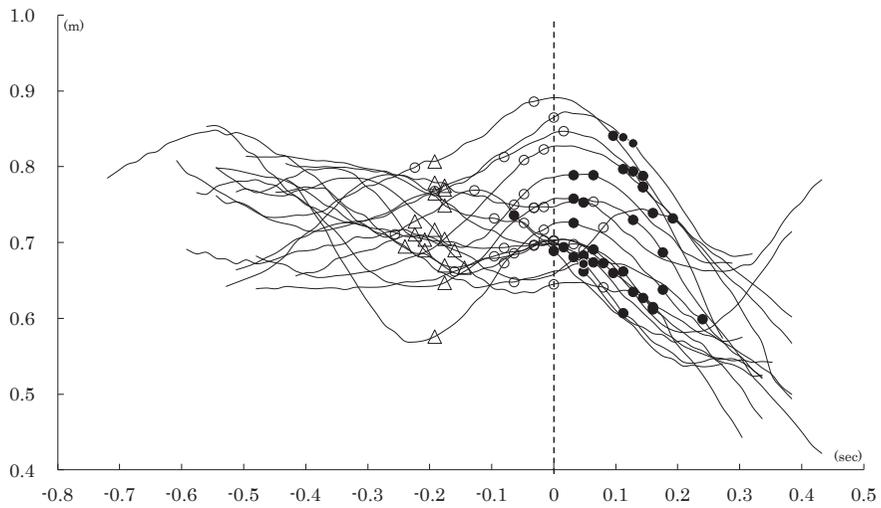


Figure 6 Up-down hip joint movements of liberos

Figure 6 illustrates up-down hip joint movements of liberos during the time from the spiker's first two steps of approach at the takeoff, to receive impacts. The horizontal axis indicates the time, and the vertical axis shows the height, zero time shows when a spiker attacks. ○ shows the takeoff, and ● shows the landing, and △ shows the beginning of a spiker's upper arm swing.

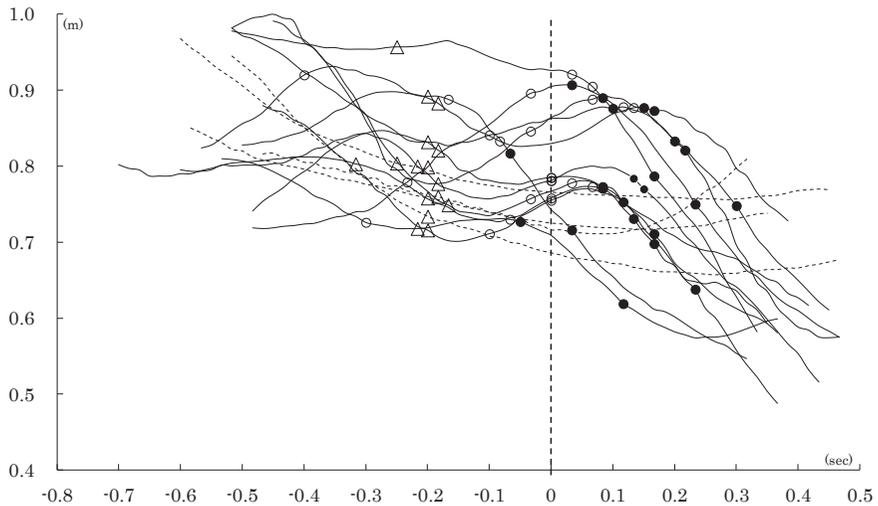


Figure 7 Up-down hip joint movements of other players except for liberos

Figure 7 illustrates up-down hip joint movements of other players during the time from the spiker's first two steps of approach at the takeoff, to receive impacts. The horizontal axis indicates the time, and the vertical axis shows the height, zero time shows when a spiker attacks. ○ shows the takeoff, and ● shows the landing, and △ shows the beginning of a spiker's upper arm swing. A dashed line shows trials of SRB (trials 25, 26, 27 and 28).

Table 4 Data on up-down hip joint movements

Number of trial	types of offensive actions	at the second step of spike takeoff with heel-on	at spike takeoff	at the start of upper forward swing	at the first step of pre jump off the floor	at the second step of pre jump off the floor	at the first step of pre jump on the floor	at the second step of pre jump on the floor	at spike	at receive impact
1	L	0.81	0.74	0.81	0.80	0.89	0.84	0.79	0.89	0.49
2	L	0.66	0.70	0.69	0.69	0.72	0.74	0.73	0.66	0.60
3	L	0.85	0.75	0.78	0.77	0.87	0.84	0.83	0.87	0.69
4	A	0.64	0.75	0.77	0.70	0.70	0.67	0.66	0.70	0.58
5	R	0.76	0.72	0.77	0.81	0.85	0.79	0.77	0.85	0.57
6	L	0.69	0.69	0.71	0.65	0.64	0.63	0.61	0.65	0.47
7	L	0.68	0.66	0.71	0.81	0.82	0.80	0.77	0.83	0.57
8	L	0.78	0.61	0.58	0.67	0.72	0.73	0.64	0.73	0.50
9	RB	0.79	0.84	0.73	0.71	0.77	0.74	0.69	0.69	0.54
10	RB	0.77	0.80	0.69	0.69	0.70	0.69	0.68	0.70	0.53
11	A	0.64	0.64	0.67	0.66	0.70	0.66	0.62	0.70	0.44
12	B	0.81	0.81	0.75	0.73	0.73	0.68	0.66	0.70	0.54
13	RB	0.80	0.80	0.78	0.75	0.75	0.73	0.69	0.75	0.42
14	L	0.80	0.76	0.70	0.69	0.70	0.69	0.64	0.70	0.71
15	RB	0.77	0.74	0.67	0.68	0.70	0.67	0.61	0.70	0.52
16	L	0.77	0.76	0.65	0.75	0.75	0.76	0.75	0.76	0.78
17	R	0.80	0.79	0.72	0.75	0.76	0.79	0.79	0.79	0.67
18	A	0.66	0.72	0.70	0.65	0.67	0.67	0.60	0.66	0.52
19	L	0.72	0.74	0.80	0.78	0.90	0.91	0.75	0.91	0.58
20	RB	0.98	0.91	0.83	0.84	0.88	0.88	0.75	0.86	0.61
21	L	0.74	0.83	0.80	0.78	0.78	0.78	0.77	0.78	0.52
22	RB	0.88	0.82	0.72	0.71	0.76	0.73	0.70	0.76	0.59
23	L	0.83	0.88	0.88	0.83	0.88	0.88	0.87	0.83	0.73
24	L	0.81	0.76	0.72	0.73	0.73	0.73	0.62	0.71	0.60
25	RB	0.95	0.84	0.73	n	n	n	n	0.69	0.68
26	L	0.85	0.80	0.76	n	n	n	n	0.73	0.74
27	RB	0.97	0.88	0.80	n	n	n	n	0.77	0.77
28	P	0.82	0.79	0.76	n	n	n	n	0.72	0.81
29	L	0.99	0.87	0.75	0.76	0.78	0.77	0.64	0.77	0.49
30	A	0.80	0.81	0.80	0.76	0.77	0.77	0.71	0.76	0.58
31	A	0.98	0.98	0.96	0.92	0.91	0.89	0.79	0.93	0.58
32	RB	0.98	0.93	0.78	0.85	0.89	0.83	0.82	0.86	0.58
33	L	0.80	0.81	0.82	0.79	0.79	0.77	0.75	0.79	0.62
34	RB	0.82	0.93	0.89	0.92	0.89	0.82	0.72	0.74	0.55
	Mean	0.81	0.79	0.75	0.75	0.78	0.76	0.71	0.76	0.59
	SD	0.10	0.08	0.07	0.07	0.08	0.07	0.07	0.08	0.10

(m)

SPK stands for spiker and Pr for pre jump. The numbers from 1 to 18 show trials of liberos, and the numbers from 19 to 34 for trials of other players except for liberos.

types of offensive actions: L stands for offensive actions from the left side, R for offensive actions from the right side. RB stands for back attacks from the right side, P for pipes, A for A quicks and B for B quicks.

at the second step of approach prior to spike takeoff: at the time when the second step of approach touched the floor of the court.

the start of upper forward swing: at the time when the upper forward swing started after spikers took off

at the first and second steps of pre jump off the floor of the court: at the time when the first and second steps left the floor of the court, in the pre jump movements of receivers. n shows no motion of pre jump

at the first and second steps of pre jump on the floor of the court: at the time when the first and second steps touched the floor of the court, in the pre jump movements of receivers. n shows no attachment

at spike: at the time when spikers hit.

at reception: at the time when receivers received spikes.

up-down hip joint movements: vertical distance from the floor to the midpoint of between the left and the right hip joints, at the second step of approach prior to spike takeoff, at spike takeoff, at the start of upper forward swing, at the first step of pre jump prior to the spike takeoff, at the second step of pre jump prior to spike takeoff, at the first step of pre jump prior to spike landing, at the second step of pre jump prior to spike landing, at spike and at reception.

Table 5 Data on step time

Number of trial	types of offensive actions	at the first step of pre jump off the floor	at the second step of pre jump off the floor	at the first step of pre jump on the floor	at the second step of pre jump on the floor	pre jump time
1	L	-0.233	-0.033	0.100	0.150	0.383
2	L	0.050	0.083	0.167	0.200	0.150
3	L	-0.200	0.000	0.117	0.133	0.333
4	A	-0.033	0.033	0.083	0.100	0.133
5	R	-0.083	0.017	0.133	0.150	0.233
6	L	0.000	0.083	0.150	0.167	0.167
7	L	-0.050	-0.017	0.117	0.150	0.200
8	L	-0.083	-0.017	0.033	0.183	0.267
9	RB	-0.267	-0.133	-0.067	0.000	0.267
10	RB	-0.067	-0.033	0.017	0.050	0.117
11	A	-0.167	0.000	0.117	0.167	0.333
12	B	-0.100	-0.050	0.033	0.050	0.150
13	RB	-0.017	0.067	0.133	0.183	0.200
14	L	-0.083	0.000	0.067	0.133	0.217
15	RB	-0.100	-0.017	0.050	0.117	0.217
16	L	-0.033	-0.033	0.033	0.050	0.083
17	R	-0.067	-0.050	0.033	0.067	0.133
18	A	-0.067	0.050	0.067	0.250	0.317
	Mean	-0.089	-0.003	0.077	0.128	0.217
	SD	0.081	0.054	0.058	0.064	0.085
19	L	-0.233	-0.033	0.033	0.233	0.467
20	RB	-0.100	0.117	0.100	0.300	0.400
21	L	0.000	0.000	0.133	0.150	0.150
22	RB	-0.100	0.000	0.133	0.167	0.267
23	L	-0.083	0.133	0.150	0.167	0.250
24	L	-0.300	-0.067	-0.050	0.117	0.417
25	RB	n	n	n	n	n
26	L	n	n	n	n	n
27	RB	n	n	n	n	n
28	P	n	n	n	n	n
29	L	-0.033	0.033	0.083	0.233	0.267
30	A	0.000	0.067	0.083	0.167	0.167
31	A	0.033	0.067	0.083	0.167	0.133
32	RB	-0.033	0.067	0.200	0.217	0.250
33	L	0.000	0.000	0.083	0.117	0.117
34	RB	-0.400	-0.167	-0.067	0.033	0.433
	Mean	-0.104	0.018	0.081	0.172	0.276
	SD	0.136	0.083	0.077	0.069	0.125

(sec)

The numbers from 1 to 18 show trials of liberos, and the numbers from 19 to 34 for trials of other players except for liberos.

types of offensive actions: L stands for offensive actions from the left side, R for offensive actions from the right side. RB stands for back attacks from the right side, P for pipes, A for A quicks and B for B quicks.

at the second step of approach prior to spike takeoff: at the time when the second step of approach touched the floor of the court.

the start of upper forward swing: at the time when the upper forward swing started after spikers took off

at the first and second steps of pre jump off the floor of the court: at the time when the first and second steps left the floor of the court, in the pre jump movements of receivers. n shows no motion of pre jump

at the first and second steps of pre jump on the floor of the court: at the time when the first and second steps touched the floor of the court, in the pre jump movements of receivers. n shows no attachment

at spike: at the time when spikers hit.

step time recorded: every step time from the first to the second of receivers' pre-jump movements was recorded, with the attack time set to 0 second. Pr stands for pre jump. n shows no motion of pre jump and no attachment.

pre jump time: time from the first step off the floor to the second step on the floor.

pointed out that the up-down hip joint of volleyball setters changed parabolically around serve receive impacts and reported that top level setters make the same split step as tennis players do. Furthermore, Nakayashiki (1980) reported in an investigation of university soccer players that it was possible for skilled goal keepers to make stronger main actions than simple counter movements because skilled goal keepers could make pre jump movements right before kicks while other non-skilled players couldn't.

Judging from these reports, as pre jump movements can be found in almost all the trials for receiving actions done by top level players in this investigation although different in the amount and timing of up-down hip joint movements. So, receivers react to high speed balls by preparing so that they can move quickly with the help of the landing reaction force.

However, pre jump movements and their timing varied for other players except for liberos and became more varied when compared to liberos' pre jump movements and timing. In most of trials done by liberos, pre jump movements were recognized after up-down hip joint movements started to become higher and after spikers' forearm swings began.

This data agrees with Selinger and Ackermann's (1986, p.209) research which points out "The preparatory movement starts after the opposing team's spiker jumps and ends when she begins her forward arm swing" because up-down hip joint movements become lower for pre jump movements before forearm swings. Preparatory movements against these spikers' hits and their timings of liberos, that is, pre jump movement and its timing, are essential factors to prevent liberos from losing points.

7. Defense Range of Receivers

In order to examine the defense range of receivers, Figures 8-1, 8-2, and 8-3 show a top view, a lateral view, and a back view, respectively. In those views the relative positions of the ball are shown with the origin at the midpoint between the left and right hip centers of the receivers just prior to receive impacts (the second step of pre jump on the floor), and a coordinate rotation of vectors from the left hip to the right hip of the receivers is performed and, unified to the direction of the sideline. ○ represents liberos and ● represents other players. As for trials 25 to 28, pre jumps were not detected, so, for convenience's sake, 0.172 sec. (Table 5), the average of other players, were estimated as the second step of pre jump on the floor.

In each table, the relative positions to the ball ranged from -0.73 m to 0.77 m in the right-leftward direction with -0.03 m as the average, from 0.27 m to 1.05 m in the for-backward direction with 0.57 m as the average, and from 0.41 m to 0.54 m in the vertical direction with 0.06 m as the average.

As for liberos, the relative positions to the ball ranged from -0.59 m to 0.77 m in the right-leftward direction with -0.03 m as the average, from 1.05 m to 0.27 m in the for-backward direction with 0.51 m as the average, and from -0.22 m to 0.54 m in the vertical direction with 0.11 m as the average. On the contrary, the relative positions to the ball for other receivers ranged from -0.73 m to 0.63 m in the right-leftward direction with -0.03 m as the average, from 0.84 m to 0.40 m in the for-backward direction with 0.64 m as the average, and from -0.41 m to 0.39 m in the vertical direction with 0.00 m as the average.

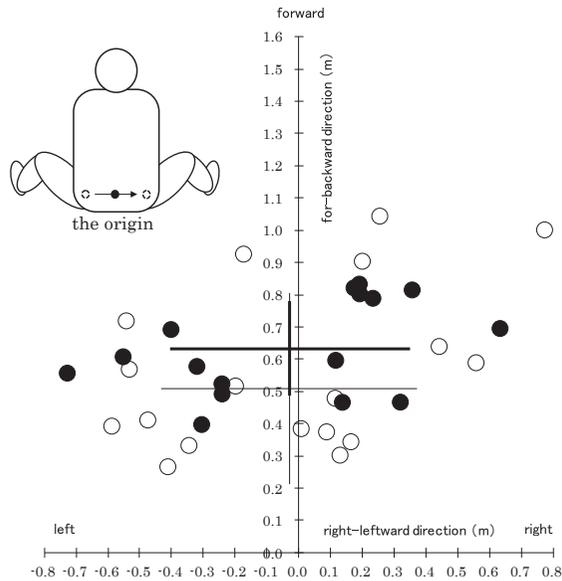


Figure 8 - 1 Top-views of defense range of receivers (after coordinate rotation)

The relative position between ready posture (the origin) just prior to receive impacts (the second step of pre jump on the floor) and the ball. Figure 8-1 shows top-views, in which a coordinate rotation of vectors from the left hip to the right hip of the receivers is performed and, integrated to the direction of the sideline. The origin is at the midpoint between the left and right hip joints. ○ stands for liberos, and ● for other players except for liberos. + signifies the mean ± 1 standard deviation. Narrow + stands for liberos.

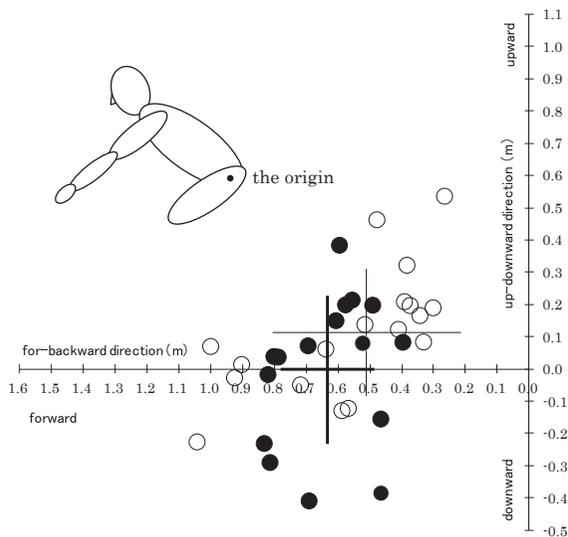


Figure 8 - 2 Lateral-views of defense range of receivers (after coordinate rotation)

The relative position between ready posture (the origin) just prior to receive impacts (the second step of pre jump on the floor) and the ball. Figure 8-2 shows lateral-views, in which a coordinate rotation of vectors from the left hip to the right hip of the receivers is performed and, integrated to the direction of the sideline. The origin is at the midpoint between the left and right hip joints. ○ stands for liberos, and ● for other players except for liberos. + signifies the mean ± 1 standard deviation. Narrow + stands for liberos.

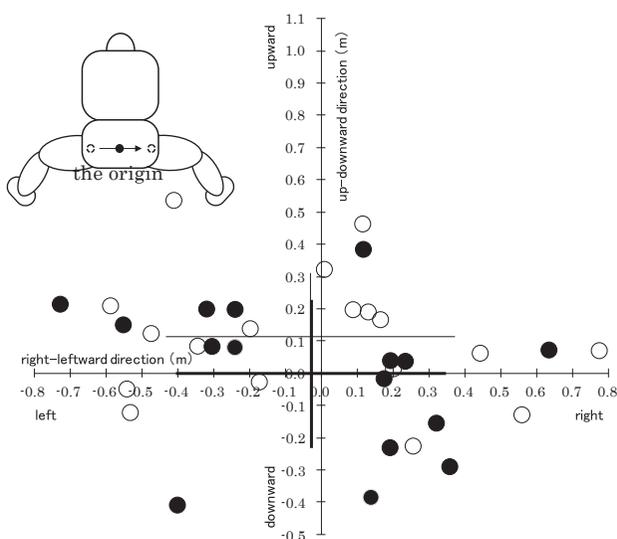


Figure 8 - 3 Back-views of defense range of receivers (after coordinate rotation)

The relative position between ready posture (the origin) just prior to receive impacts (the second step of pre jump on the floor) and the ball. Figure 8-3 shows back-views, in which a coordinate rotation of vectors from the left hip to the right hip of the receivers is performed and, integrated to the direction of the sideline. The origin is at the midpoint between the left and right hip joints. ○ stands for liberos, and ● for other players except for liberos. + signifies the mean ± 1 standard deviation. Narrow + stands for liberos.

Looking at liberos' receiving positions in the for-backward direction, these positions varied far more than other receivers. Therefore, the range of liberos' receiving positions in the for-backward direction was wider than that of other players.

These results indicate the receiving range from the ready position right before receive impacts (the midpoint between the left and right hip). The time from spike hits to receive impacts averages 0.376 sec (SD=0.055) (Table 2) and the time at the second step on the floor averages 0.146 sec (SD=0.068). So there is very little time for receivers because the ball takes an average of 0.23 sec after receivers take position at the same time of pre jump landing. In short, receivers cannot receive the ball by moving with either foot taking one step forward from their positions. Therefore, they received the ball by moving within a range of approximately ± 0.7 m in the right-leftward direction, between 0.27 m and 1.0m in the for-backward direction, and between -0.41 m and 0.54 m in the up-downward direction from their positions before the impacts.

IV. Coaching Suggestions

In games categorized as low speed ball, the receiving posture to position forearms parallel to the court floor (Toyoda & Furusawa, 1982) can be more effective for both underhand and overhand passes (Kaneko, 2001, p.7). However, in games categorized as high speed ball, Coleman and ColemaNesst (1994, p.73) asserted that there is no or little time from hits to receive impacts, and so lowering both

hands and putting both arms together soon after hits might be more effective. Moreover, judging from game situations in which players received impacts with their upper arms as well as forearms during receive impacts, players need to form platforms with their whole arms so that they can respond to the hits coming at their chests, and so it may be effective to form a platform with both arms during basic drills and to practice receiving actual hits with various parts of a platform.

As for lower extremity movements, players are able to receive high speed balls if they prepare to respond to hits with assistance of landing reacting to pre jump movements by taking postures after they go into the hitting course and take postures via pre jump movements.

As for the receiving skills for hard hit attacks examined from top level players in this investigation, motions such as using pre jump as a preparatory movement right before hits and not bending their elbows too much so that they can form a platform very quickly with both arms can be skills even top level players should practice. In the research Nagai (1998) and Yoshihara (1966) examined when players should start to learn volleyball and they showed that it should be when players are in the fifth or sixth grade of elementary school. Although there are differences between their focus and this investigation's focus, the ready posture necessary for underhand passing skills and passing movements are basic volleyball skills and should be introduced at the very first stage of practice drills (Nagai, 1998, p.109). Volleyball is part of the physical education courses for the 1st year junior high school students according to the official curriculum guidelines in Showa 26 (Ministry of Education, Culture, Sports, Science and Technology, 1951), and development of such jumping motions as hopping, skipping and galloping should be acquired later in the higher grades of elementary school (Winnick, 1979, Chapter3). Thus, the main conclusions of this investigation should be introduced in the early stages of students learning to play volleyball.

Moreover, taking position as a receiver depends on reading the hitting direction and timing. These skills, reading the hitting direction and timing, can be introduced to beginners (Japan Volleyball Association, 1988, p.72). Therefore, it is essential for coaches to teach players to take position via pre jump movements by closely observing spikers and going into the hitting course and to practice these skills in phases, so that they can extend both hands reflexively to respond to the strong high speed balls in a short amount of time, based on the ready postures supported by Toyoda and Furusawa (1982).

V. Conclusion

The balls hit by top level men's players are difficult offensive attacks to receive. By examining how the top level players react to high speed balls and achieve motion effects, this investigation tries to exemplify top level players' spike receiving skills against spikes. The main results are summarized below:

1. 47 % of the defensive actions against hard hits (477) allows opponents to score without touching blockers or receivers (successful spikes). The number of digs without one touch blocking which cannot be returned to the opponent's court because the rally cannot continue is 122 (lost points by

dig error), accounting for 26 %. Thus, successful digs accounts for only 14 % of the total and that suggests it is difficult for top level-male players to receive balls at high speed.

2. The positions of passing the balls in the trials ranged from 1.48 m to 7.57 m and averaged 4.44 m (SD=1.45) and the positions from the sideline ranged from 0.41 m to 8.10 m and averaged 4.27 m (SD=1.54). Although there was a large variation, these data show that receivers tried to return the ball as close to the center of the court as possible.
3. The positions at receive impacts of liberos who were playing at left back in the examined trials ranged from 3.55 m to 6.80 m from the center line and averaged 5.39 m (SD = 0.91) and the positions from the sideline ranged from 0.66 m to 2.77 m and averaged 1.79 m (SD=0.72).
4. The relative positions between the ball and the midpoints between left and right shoulder joints of the receivers at receive impacts (Figures 4-1 and 4-2), ranged from -0.28 m to 0.35 m in the right-leftward direction with 0.01 m as the average, from -0.62 m to -0.13 m in forward and backward direction with -0.42 m as the average, and from -0.31 m to 0.06 m in the vertical direction with -0.21 m as the average. On top level men's players, because players have no time to put both hands low with elbows extended and form a flat platform with both arms, it might be better for players to lower their hands rather than to extend them forward, and form a flat platform by extending their elbows right after hits.
5. Because the ball arrives in an average of 0.23 sec after receivers take position at the same time of pre jump landing, the time is too short time for receivers to receive the ball by moving. Therefore, they received the ball by taking position before the impacts, within the range of approximately ± 0.7 m in the right-leftward direction, between 0.27 m and 1.0m in the for-backward direction, and between -0.41 m and 0.54 m in the up-downward direction.
6. Up-down hip joint movements of receivers (Figures 6 and 7) shows that their up-down hip joints usually became higher at hits, and then, ① they became lower before receiving impacts, ② they became flat right before receiving impacts, ③ after the second step on the floor, up—down hip joint movements became higher before received impacts. As for liberos' step time (Table 5), liberos made a pre jump movement prior to hits in almost all the trials.

In this research, total defensive actions including spikers and blockers were not examined. Receive positions vary with game situations because spikers' attacking positions and blockers' positions and which course blockers could block and so forth affected receiving positions. Therefore, further research on total defensive movements need to be done.

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本研究は、強打されたスパイクに対するレシーブ技術について、一流選手のレシーブ技術を明らかにすることを目的とした。対象試技は、2011 ワールドカップバレーボール男子大会における6試合27セットから競技中の強打スパイクに対するレシーブ動作994回とした。レシーブ技能を評価した後、アンダーハンドによるレシーブ動作34試技を抽出しDLT法により3次元座標を構築し分析したところ以下の結果が得られた。

- (1) ブロックに接触しなかったスパイクを守備した477回の内、レシーバーは200回(42%)の強打スパイクに触球したが、レシーブ成功しカウンター攻撃に至るのは69回(14%)であった。
- (2) リベロのレシーブ失点は、他の選手と比較して低かった。
- (3) レシーブ時の位置取りについては、リベロは18試技全てにおいて後衛レフトに位置していた。
- (4) リベロの腰部高変化とステップについて、腰部高は概ね打撃時付近に最も高くなっていた。また、ほとんどの試技でリベロは打撃時より前にプレジャンプ動作を開始していた。

キーワード：バレーボール、スパイクレシーブ、一流男子選手、リベロ

