AN ANALYTICAL STUDY OF BASIC SKILLS IN VOLLEYBALL

— MOTION ANALYSIS OF UNDERHAND PASS, TOSS, AND STEP-IN MOTION IN SPIKING —

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Introduction

A considerable amount of studies^{2) 10) 11)} on the volleyball skills has been reported. However, the informations on the method of kinematographic analysis are quite scarce. Although the literature such as Ishiguro⁴⁾, Yamamoto^{18) 19)}, Takahashi^{16) 17)}, Miura¹²⁾, and Kawai^{6) 7)} are serving as the source of information in this particular area, the accumulated results may be still insufficient. Especially on the passing and spiking motions which should be one of the most fundamental skills in volleyball, there is no information available based upon kinesiological analysis.

While players move unconsciously of their forms, it is of no practical use to give instructions about the body movements to them while playing.

Johnson⁵⁾ insists that at least four factors are necessary to take into consideration as the variables of skills of an exercise, namely speed, accuracy, form and adaptability, upon an analysis of woodcutter contests.

The present report intends to analyse the components in passing, tossing, and spiking in the sport of volleyball by use of kinematographic analysis, and to obtain some useful informations in objectively instructing¹⁾ basic skills of volleyball.

Method

1. Subjects

The subjects were eleven male volleyball players actively taking part as the regular players in the varsity volleyball team of Juntendo University, which is ranked at the top level in the Kanto Intercollegiate Volleyball First League.

As the subjects of underhand pass four players were used, and two for overhand pass form. For toss form two setters were used. In experiments of spiking form three attackers were used and two non-volleyball players were also used as inexperienced subjects. Their measures of physique were listed in Table 1.

Table 1. Physique of the subjects

Experiment	Subject	Height (cm)	Weight (kg)	Position
Toss Play	K. Kin	179.0	78.0	Setter
	Y. Hayashi	172.0	65.0	Setter
	K. Furukawa	171.5	72.5	Attacker
	H. Ōtake	172.4	70.6	Attacker
Spiking Form	K. Hoshino	173.5	65.5	Attacker
	K. Uchida	171.5	65.6	Track
	Y. Ogura	169.3	64.8	Tennis
	S. Nakao	174.5	65.5	Setter
Underhand Pass	K. Aizawa	174.8	65.5	Setter
	T. Sakashita	172.0	64.0	Setter
	S. Mine	172.0	60.1	Setter

Of the six subjects listed above last four are used in analysis of underhand pass form, and the first two are for overhand pass forms.

2. Experimental Procedure

1) Underhand Pass Form

a) The subjects wore only bathing trunks and a pair of volleyball shoes. For the reference points in the film analysis, the following points of the body of each subject were marked with a white tape: tip of the chin, tragus of ear, acromion, iliac crest, external malleolus, lateral epicondyle of humerus, and styloid process of ulna.

b) In order to obtain a clear photographic image, a dark screen was provided behind the subject, which was marked in black and white at the end establishing a scale for analysis. The direction, height and the nature of the flight of the passed ball were recorded subjectively for the future reference.

c) A 16mm. Bolex camera was fixed in front of the subject at the distance of 11.57 meters. The movement of the subject was photographed with the film speed 64 frames/sec in all the cases of these experiments.

d) A regulation volleyball was hung from the ceiling at a height 10cm. above the knee joints of the subjects. Using the ball, each subject executed two passes respectively to the two target areas shown in Figure 1. The two target areas were defined as follows:
(P₁) area between the center line and the attack line, to which a short pass just going

Figure 1. Layout of Experimental Condition

over the net was aimed; (P₂) area close to the end line, to which a long pass was executed. These two conditions, hereinafter, are abbreviated as P₁ and P₂.

2) Overhand Pass Form

a) The subjects wore bathing trunks and a pair of volleyball shoes. The same points of reference as in the case of underhand pass were used for analysis and were marked with a white tape.

b) The back wall with grid provided with white lines both in horizontally and vertically in 20cm×20cm sections for reference scale was used. The height, direction and the nature of the passed ball were recorded by use of the grid.

3) Toss From

a) The players wore bathing trunks and a pair of volleyball shoes. The same points of body as in the case of former passes were used for analysis and marked with a white tape.

b) In order to establish a reference scale, a wall one meter apart from the player on his right, marked with white lines both in horizontally and vertically in 20cm×20cm sections.

c) To photograph the movements of the subject, two cameras were used at the same time. Camera A was fixed in the side of the subject at the distance of 10 meters. And Camera B was aiming at the flight of the tossed ball at the distance of 20 meters. The lenses of both cameras were fixed at the height 1.8 meters above the floor.

d) The subject stood parallel with the wall at 1 meter apart from it, and set up the ball. The description of the desired toss was as follows: the height was 5 meters and the distance of flight, 6 meters. The subjects tried to toss conforming with the description for several times.

4) Spike Form

a) The subjects wore bathing trunks and a pair of volleyball shoes. The same points of body as in the cases of passes and toss were used and marked with a white tape.

b) In order to obtain a reference scale, the floor was marked with white lines like in the case of toss.

c) To analyse the movements of spike form, a camera was set in the right side of the player at the distance of 10 meters. The lense of the camera was at the height 1.8 meters above the floor.

d) The subject stood at 3 or 4 meters apart from the net and opposite to a setter. He tried to spike the ball several times which was set up by the setter at the height of 3 or 4 meters above the floor.

3. Procedure of Film Analysis

The developed films were projected and examined in full detail. One film recording for each subject was selected by criteria of the excellence in form with the good balance and the conformity of the flight of the ball with the description as established for the experi-

mental condition. The selected films were studied by a motion analyser.*

1) Underhand Pass Form

The points marked on the body of the subject were plotted on each frame into loci of respective points beginning with the frame in which the finger tips of the subject in passing motion reached to the lowest point and finishing with the frame in which the finger tips of the subject in follow-through after passing reached to the highest point. The following aspects were analysed:

- a) The movement of the whole body obtained by connecting the reference points on each frame (Figures 3, 4, 5, and 6).
- b) The locus of each reference point obtained by plotting the point on the consecutive frames (Figures 7, 8, 9, 10, 11, and 12).
- c) The angles of neck, axilla, hip and knee.

On the above listed three aspects, comparison was made for the conditions of P_1 and P_2 , i.e., between the cases of short pass and long pass.

2) Toss Form

The motions of the reference points and the flight of the ball were analysed taking every other frame in the case of Camera A and every ten frames from Camera B. The following aspects were examined:

- a) The loci of the height and the distance of the tossed ball.
- b) The locus of the tossed ball which moved with increasing speed like a parabola.
- c) The initial velocity of the tossed ball.
- d) The direction of the tossed ball.
- e) The ratio of the horizontal and vertical vector components of the initial direction of the tossed ball.
- f) The connection between the initial direction and the movements of the each points of the body.

3) Spike Form

Selecting every three frames from the film, the motions of the reference points and the flight of the ball were analysed. Moreover, the comparison between volleyball player and non-volleyball players was made with regard to the following aspects³⁾:

- a) The speed and the stride of the last step in step-in motion.
- b) The locus marked on the movement of the center of gravity of the body in all process of spiking.
- c) The movement of the arm which seems to be the most practical and effective.
- d) The spike form.

*Produced by Nack Co.

Results and Discussions

1. Underhand Pass Form

1) Whole Body Movements

Case of subject S.N. (Figure 2): The difference between the conditions P_1 and P_2 can be observed in the movement of wrist after the impact of the hands with the ball. While the wrist was flexed upwards in P_1 , it was flexed downwards in P_2 . As to the inclination of the body, an upward extension in vertical direction was observed in P_1 , in contrast, the body was extended diagonally up-forwards in P_2 . In comparison with the case in P_1 , the greater backswing in P_2 was observed.

Figure 2. Simulated Body Move: S.N.

Case of subject K.A. (Figure 3): At the moment of impact, the flexion of wrists were upwards in P_1 and downwards in P_2 . In comparison with the case in P_1 , the hip was further drawn back-downwards in P_2 in accordance with the greater back-swing necessary for the condition.

Case of subject T.S. (Figure 4): The difference between P_1 and P_2 was quite prominent in the flexions of the wrists at the moment of impact. From the movements of the upper body, it was proved that the subject followed the ball with his eyes after passing, both in the cases of P_1 and P_2 . The greater back-swing in P_2 was observed in comparison with the condition of P_1 .

Figure 3. Simulated Body Move: K.A.

Figure 4. Simulated Body Move: T.S.

Case of subject S.M.: (Figure 5) Little difference was found between P_1 and P_2 in the flexion of the wrist and the motions of back-swing. However, the upper body in P_1 was more vertical, in contrast with that of P_2 .

Figure 5. Simulated Body Move: S.M.

Among the four subjects used for the present investigation, the general trends were approximately in agreement. However, considerable differences were found when the two conditions of P_1 and P_2 were compared. These differences are listed as follows:

a) A difference was found in the wrist actions immediately after the impact of the hands with the ball. In the condition P_1 , the wrist was flexed upwards as the movement proceeds into follow-through. In contrast, the wrist was flexed downwards in condition P_2 .

b) The movement of the back-swing was larger in P_2 than it was in P_1 . All the subjects agreed upon this trend.

c) As to the inclination of the upper body immediately after the impact, the subjects tended to keep their bodies in an upright vertical position in P_1 , while their bodies were held in a diagonally slanted position in P_2 . However, as it was observed in the case of S.N., a considerable variation in the movement of the upper body was found which may be associated with the peculiar characteristic of the individual player apart from the general trend.

2) Loci of the Reference Points

Locus of the shoulder (Figure 6): The movement of the acromion was roughly in the direction of vertically upward. The four subjects approximately agreed on this

trend. The locus obtained for the condition of P_2 was slightly inclined in the direction of diagonally up-forward, in contrast with that of P_1 . The subject S.N. showed a trend of up-backward movement both in the conditions of P_1 and P_2 .

Locus of the hip (Figure 7): The loci of the four subjects shared approximately the same trend. The point marked on the iliac crest traveled in the direction of up-forward. In comparison with the case of P_1 , the locus in the condition of P_2 showed greater inclination against the floor even before the ball was first touched with the fingers.

Locus of the knee (Figure 8): A marked individual difference was found among the movements of the knee of the four subjects before the impact of the hands with the ball. This may be caused by the different method of timing employed by the subjects. However, considerable uniformity in the movements was observed after the impact. Immediately after the impact, the knees were pushed forward, and then they were moved back-upwards in follow-through. This movement of the knees immediately after the impact was quite interesting.

Locus of the elbow (Figure 9): Between the conditions of P_1 and P_2 , a considerable difference was observed in the movements of the elbow from the highest point of the back-swing to the moment of the impact. The arc of the locus in P_2 was more slack, whereas the arc in P_2 was sharper in the upward movement.

Figure 6. Locus of the shoulder

Figure 7. Locus of the hip

Figure 8. Locus of the knee.

Figure 9. Locus of the elbow.

Locus of the finger tips (Figure 10): Both in P_1 and P_2 , the locus of the finger tips showed a downward movement from the highest point in back-swing, and thereafter it showed an upward motion in an arc. In contrast with the case of P_2 , however, the circular movement up to the highest point in the follow-through was larger in P_1 .

Therefore, the loci of the reference points showed these trends like followings:

a) Locus of the shoulder:

All the four subjects agreed in the vertical movement of their shoulder. The locus in P_2 , in contrast with that of P_1 , showed a movement in a direction of diagonally up-forwards.

b) Locus of the hip: In the condition of P_2 , as compared with P_1 , the locus of the hip showed a greater inclination against the floor in its movement in up-forward direction. As the movements of the shoulder and hip have a direct bearing with the ball control in relation with the movement of the arms and wrists, the direction of the movement in P_2 in which a longer pass was attempted tended to be slanted in diagonally up-forwards. The movement was in vertical upright in P_1 in which a short pass just going over the net was intended.

c) Locus of the knee: Marked differences were observed in the motion of the knee before the impact of the hands with the ball. These differences may be caused by the difference in timing characteristic to the individual player. Immediately after the impact, the knee showed a forward movement for a short while, and then it was pulled backwards. This forward motion of the knee was considered as an evidence that the pass was executed utilizing the whole body.

d) Locus of the elbow: The motion of the elbow after the impact of the hands with the ball showed a rise with a sharper arc in P_1 , in contrast with the case of P_2 in which the arc was more slack. The four subjects showed a similar trend.

e) Locus of the finger tips: The downward movement of the finger tips from the highest point in the backswing indicated that the wrists of the subjects were flexed backwards. The locus in the condition P_1 showed the arc higher up to the highest point in the follow-through than in the condition P_2 . This fact indicated that the wrist was flexed upwards in P_1 as the motion proceeded into follow-through. This finding was in agreement with the observations made on the difference of the total body motions in P_1 and P_2 .

Figure 10. Locus at the finger tips

3) Angles of the Reference Points at the Movement of Impact

Angle of the ankle (toe-external malleolus-external tuberosity of tibia): The angle of the ankle in P_2 was greater than that of P_1 for the subject S.N., whereas the trend was in reverse direction in T.S. and S.M. In every instance the difference was quite small. The recordings of subject K.A. were omitted due to incomplete filmings.

Angle of the knee (external malleolus-external tuberosity of tibia-iliac crest): The angle of the knee was larger in P_2 than it was in P_1 in all of the four subjects. The difference was largest for the subjects S.N. (24°) and S.M. (16°), while the smallest difference was found for T.S. (7°).

Angle of the hips (external tuberosity of tibia-iliac crest-acromion): The larger hip angle in the condition P_2 in comparison with P_1 was registered by all the subjects. However, the difference in the angles between P_1 and P_2 was quite small for the subjects S.N. and K.A.; 1° and 2° , respectively. The greater difference was observed for T.S. and S.M.; the difference was 19° and 49° , respectively.

Angle of the axilla (lateral epicondyle of humerus-acromion-iliac crest): With an exception of the subject S.N., all subjects showed greater axilla angle in the condition of P_1 than that of P_2 .

The largest difference between P_1 and P_2 was 26° registered by K.A. The subjects T.S. and S.M. showed the difference 2° and 6° , respectively. The subjects S.N. demonstrated a larger angle in P_2 over P_1 , the difference being 19° .

Angle of the neck (tragus of ear-acromion-iliac crest): Here again, the subject S.N. showed a deviation from the other three subjects. Larger neck angle was registered by the three subjects in P_1 , while S.N. registered a reversed trend. The differences between the angles in P_1 and P_2 for K.A., T.S., and S.M. were 18° , 1° , and 7° , respectively. In the case of S.N., the angle for the condition P_2 was 9° larger than that of P_1 .

2. Toss Form

By use of the motion analyser, the following results, as presented in Figures 11~14, were obtained.

The results of the present investigation were shown by Table 3 and Table 4 in detail, which were studied on the distance and the height of the flight of the ball, the initial velocity, the vector components of the flight of the ball, and the angles of movements of the ball and the reference points against the body.

Table 2. Angles of ankle, knee, hip, axilla and neck at the moment of first impact of the hands with the ball (degrees).

Subject	Condition	Ankle	Knee	Hip	Axilla	Neck
S.N.	P 1	75	60	110	48	174
	P 2	77	84	111	67	183
K.A.	P 1	88	98	87	110	185
	P 2	—	110	89	84	167
T.S.	P 1	74	77	98	64	194
	P 2	70	84	117	62	193
S.M.	P 1	72	75	72	84	204
	P 2	65	91	121	78	197

Figure 12.

Figure 11.

Figure 13.

Note: In Figures 11~14, (A) shows the loci of the tossed ball and of the reference points marked on the body, which were taken by Camera A from a distance of 10 meters. (B) shows the locus of the ball, which was obtained by Camera B at the distance of 20 meters.

Figure 14.

Table 3. Flight of the Passed Ball; (Height, Distance, Initial Velocity)

Subject	Experiment No.	Flight of Ball		Initial Velocity (m/sec)
		Distance (m)	Height (m)	
K.K.	No. 1	5.85	4.40	10.78
	2	5.80	4.80	10.78
	3	5.95	4.92	10.81
	4	5.88	4.73	10.70
	5	6.10	5.05	10.80
Y.H.	No. 1	6.15	4.63	10.61
	2	6.00	4.52	10.28
	3	5.85	4.73	10.38
	4	5.90	4.80	10.40
	5	6.00	5.10	10.75
Mean		5.95	4.77	10.63
Standard Deviation		.10	.21	.19
Standard Error of the Mean		.034	.69	.063

*Note: The value obtained by measuring the distance traveled from the first frame to the next frame and dividing the distance by the frame speed.

Table 4. Vector Components of the Flight of the Ball and Angles of Movement
of the Ball and Reference Points against the Body

Subject	Experiment No.	Vector Components		Angles to Motion against the Floor (degrees)		
		Horizontal	Vertical	Ball	Tragus of ear	Iliac crest
K.K.	No. 1	0.5095	1	63	76	80
	2	0.4663	1	65	63	68
	3	0.4877	1	64	77	76
	4	0.5095	1	63	75	78
	5	0.4877	1	64	70	69
Y.H.	No. 1	0.4452	1	66	79	76
	2	0.4877	1	64	82	62
	3	0.4452	1	66	76	75
	4	0.4663	1	65	77	74
	5	0.5095	1	63	68	73
Mean ($\bar{x}$)		0.4815	1	64.3	74.3	73.1
Standard Deviation (σ)		0.0245		1.10	5.37	5.11
Standard Error of the Mean ($\sigma\bar{x}$)		0.0078		.367	1.789	1.703

$$*\sigma\bar{x} = \frac{S.D.}{\sqrt{N-1}}$$

1) The Distance and the Height of the Flight of the Ball

The present investigation was made under the condition where the distance was 6 meters and the height was 5 meters. The result of the investigation was almost identical with the condition practically. In the consequence of the experiment these values as follows were obtained :

	Mean	Standard Deviation	Standard Error of the Mean
Distance	5.95m	0.10	0.034
Height	4.77m	0.21	0.069

2) The Locus of the Tossed Ball

The loci of the tossed ball, which were described in Figures 11-14 (B), showed the movements of the ball which moved with increasing speed like a parabola.

In order to pass and toss the ball up it was necessary to know beforehand the movement of the ball correctly and quickly and to complete the perceptual differential calculus of the position and timing to pass the ball. For the purpose of the differential calculus, synthetic faculty was required in the case of not only the sense of sight but also the sense of equilibrium and that of muscles.

3) The Initial Velocity and the Direction of the Tossed Ball

By the present experiment, these values were obtained as follows :

	Mean	Standard Deviation	Standard Error of the Mean
Initial Velocity	10.63m	0.10	0.034
Initial Distance	4.77m	0.21	0.69

It would be rather possible to increase the initial velocity. However, the present investigation clarified that it was necessary to master the highly leveled technique in order to toss a ball in the restricted range of the velocity and the angle. In other words, it was proved to be necessary to toss a ball while the central nervous system calculating and controlling the power of ball tossing according to the stimulus which was perceived by sensory nerves, and that in accordance with the calculus the muscles of the body worked correctly.

4) The Horizontal and Vertical Vector Components of the Initial Direction of the Ball

The angle of the initial direction of the tossed ball averaged 64.3° , S.D., 1.10 and $\sigma\bar{x}$, 0.37. With this angle, the ratio of the horizontal and vertical vector components were .4815 and 1.0000 (Table 4). It was possible to presume the proportion of one to horizontal and two to vertical directions. In addition, the beginners tended to notice the horizontal vector component more important than the vertical one. This should be an important key point in the instruction of the beginners.

5) The Relationships between the Initial Direction and the Motions of Each Point of the Body

Before the experiment, it was expected that the initial direction of the ball would become connected with the iliac crest, which particularly showed the movement of the body, and the tragus of ear which approximated the center of gravity psychologically¹³⁾. However, the relationship between the two were formed to be almost negligible.

	Mean	Standard Deviation	Standard Error of the Mean
Angle of Movement of Iliac Crest against Floor	74.30	5.37	1.789
Angle of Movement of Tragus Ear against Floor	73.1	5.11	1.703

4. Spike Form

The technique of spiking was based on the motion of legs, that is to say, step-in motion. The energy of spike movement was owing to the speed of step-in motion.

1) The Speed and the Stride of the Last Step in Step-in Motion

In Table 5, the data of the speed and stride of the last step in step-in motion are described :

Table 5. Speed and Stride of the Last Step in Step-in Motion

	Name	Stride	Frames	Speed
	Unit	cm	64per. sec.	cm/sec
Skilled	Furukawa	232	31	483
		225	31	469
		218	30	464
	Ôtake	165	30	351
		175	30	372
		171	32	342
	Hoshino	216	30	458
		200	29	442
		186	27	441
Unskilled	Ogura	140	33	297
		140	32	280
		133	30	255
	Uchida	154	34	300
		112	28	254
		112	26	273
Average	Skilled	198.7	30	424.7
	Unskilled	131.8	30.5	276.5

The minimum speed of the skilled was larger than the maximum of the unskilled and the proportion of the two was 10: 6.5, which was almost 3: 2. The difference between them were found to be considerably large. The cause of the difference was related to the value of the stride. Consequently, it was recognized that the speed was connected with the stride deeply. In comparison with the step of the running-shoot of basketball and the take-off of the broad jump or of a long horse vaulting, the characteristic of the step-in movement of volleyball was that, the preparatory running distance before the step-in was quite shorter.

The fast speed gained by the wide stride of the last step was the basic condition for the timely spiking as well as for higher jumping and strong spiking. Because the unskilled felt uncertain and anxious about the correctness of his own position and timing so that he could not step-in as good as he wanted, and consequently, his stride was small and his speed was slow. Therefore, in order to make progress in spiking, it should be the first indispensable condition for the unskilled to recognize the phenomenon and to improve it.

2) The Locus Marked on the Movement of the Center of Gravity of the Body in Whole Process of Spiking

The cinematographic changes during spike motion of the skilled and unskilled were described in Figures 15 and 16.

The loci of iliac crest, traced from the total body moves shown in Figures 15 and 16, when illustrated, are presented in Figures 17 and 18.

Figure 15. Simulated Body Move during Spike: Furukawa (skilled)

Figure 16. Simulated Body Move during Spike: Ogura (unskilled)

Figure 17. Loci of Iliac Crest (every 3 frames), Upper Two Traces: Furukawa (skilled), Lower Two: Hoshino (skilled)

Figure 18. Loci of Iliac Crest (every 3 frames), Upper Two Traces: Uchida (unskilled), Lower Two: Ogura (unskilled)

In Figure 17 the locus of the hip showed a greater inclination toward the floor. This may be due to change in the speed forward to power upward. In addition, the knee was straightened, which was shown at 107th frame in Figure 15. Consequently, the loci described in Figure 17 were stabilized on the whole.

In Figure 18 the unskilled used to move the hip downward and the knee was bent a little as described at 115th frame in Figure 16. In this way the loci in Figure 18 were not stabilized like those in Figure 17.

When the unskilled ran speedily, he had to jump with greater horizontal element, while, when he ran slowly, he could not hit the ball with a greater power. It seemed to be very difficult for the unskilled to master the step-in motion completely.

3) The Motion of Arm

As a factor to make progress in step-in motion the movement of arm was suggested to be very important according to the cinematographic changes from 102th frame to 138th frame in Figure 16.

The skilled swung the arm fully from backward to upwards in order to make jumping higher. Besides, he moved the arm back above the shoulder so as to increase the power at hitting the ball. (See 141th frame in Figure 15)

On the other hand the unskilled did not move the arm enough like the skilled. After all, in order to make progress in spike form of the unskilled it must be much effective to indicate how to use the arm enough than how to move the hip and the knee.

4) The Form of Spiking

All motions of spiking, i. e., step-in, take-back, hitting and finished motions, were studied. From Figures 15 and 16, step-in motion (A), take-back motion (B), hitting motion (C), finished motion (D) were picked up into Figure 19.

The difference between the skilled and the unskilled was found in the motion of the knee and the arm in step-in motion (A). Secondly, the difference between them was

Figure 19. (A) Step-in motion into jumping
(B) Take-back motion
(C) Hitting motion
(D) Finished motion
Right side: Furukawa (skilled)
Left side: Ogura (unskilled)
M=Meet.

appeared in the bending of the body in (B). Hitting motion (C) was performed at the moment when the arms and the legs moved fastest. The hitting form of the skilled was shown as a straight line. Because he touched the ball at the middle moment of the body motion, he could hit the ball with the strongest power of the body. In this way his form was considerably effective and rational in kinetics.

Conclusion

From the present investigation in which three basic skills in volleyball, namely, underhand pass, toss form, and spike form were studied with the method of kinematographic analysis under different experimental conditions, respectively, the following conclusions and key points of the instruction were drawn:

1. Underhand Pass Form

1) When a longer pass was intended (P_2), the subjects tended to show a greater forward inclination of the total body against the floor, a greater back-swing before hitting the ball, and a downward flexion of the wrist in the follow-through. In the condition in which a shorter pass was intended (P_1), the trends were in the reverse direction.

2) In the loci of the shoulder, hip, knee, elbow and fingers, the motions toward horizontal direction were enhanced in the condition for a longer pass (P_2). In contrast, the vertical upright movements were eminent when the subject intended a short pass (P_1).

3) From the motions of the knee and the angles of the ankle, the observation that the power of the whole body as well as that of arms and hands were utilized in the passing motion was made.

4) In relation to the angles of the knee, hip, and axilla, observations were that an inefficient pass form depends largely upon the powers of arms and hands, an efficient pass form utilizes the power of the whole body effectively, and that a peculiar characteristic of the individual player was eminent in pass form.

2. Toss Form

From the investigation of the tosses with distance 5.95 meters and height 4.77 meters, the following conclusions were gained:

- 1) The initial velocity of the tossed ball was approximately 10.63m/sec, S.D. being 0.10.
- 2) The initial projection angle of the ball was 64.3° , S.D., 1.1° , $\sigma\bar{x}$, 0.36.
- 3) The vector components of the tossed ball were in proportion of two vertical to one horizontal directions.
- 4) The initial velocity of the ball had no connection with the movements of tragus of ear and iliac crest.

2. Spike Form

- 1) The proportion of the stride and speed of the step-in motion was almost 3 to 2.
- 2) In the case of the skilled in step-in motion, his hip inclined to move downward deeply and his knees were straightened in order to jump higher.
- 3) In step-in motion, the center of gravity locus of the skilled was stabilized while the unskilled was not stabilized.
- 4) The skilled used the arm fully and speedily in order to make it effective to step-in, to take-back, and to hit the ball.
- 5) The hitting form of the skilled was like a straight line.

Although the scope of the present investigation may be quite limited due to the small number of subjects studied, it was believed that the informations thus obtained may serve as the useful materials in the instructions of the basic skills in volleyball.

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