

A COMPARISON OF THE ON-HAND AND OFF-HAND
STRAIGHT SPIKES IN VOLLEYBALL

A Thesis
Presented to
the Faculty of University Schools
Lakehead University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science
in the
Theory of Coaching



by
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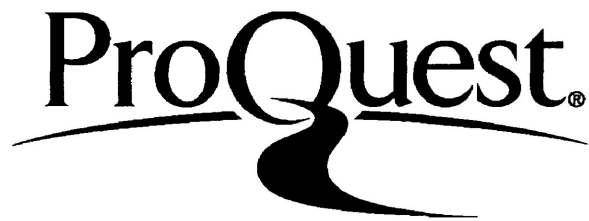
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ABSTRACT

Title of Thesis: A Comparison of the On-Hand and Off-Hand Straight Spikes in Volleyball.

Brian Luk-Ming Kan: Master of Science in the Theory of Coaching

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The purpose of this study was twofold: 1) to examine the differences between the on-hand side and off-hand side spikes in volleyball in terms of velocity and accuracy, and 2) to evaluate the relationship of the angle of projection with velocity in each spike. The subjects (N=12) were members of 1979-80 University of Alberta Volleyball Team.

The research design employed a repeated measures technique with two variables, the on-hand and off-hand spikes. Subjects were required to perform 20 straight spikes for each technique. The velocity and the angle of projection data for each trial were obtained by cinematographical analysis. Accuracy scores were collected by direct recording after each trial.

A correlated t test was used to determine the differences in velocity and accuracy between the on-hand and the off-hand spikes. A Pearson Product-moment Correlation Coefficient was used to assess the relationship between the velocity and the angle of projection of each spiking technique for each subject. A further correlated t test was used to determine differences in that relationship between the on-hand and off-hand spikes.

The results indicated that the differences between the on-hand and off-hand spikes, in terms of velocity and accuracy, were significant ($P < .05$). There was no relationship between the velocity and the angle

of projection for the on-hand spike but a low significant relationship was observed for the off-hand spike. The difference in relationship of velocity and angle of projection between both spiking techniques was not significant. Several recommendations for future researches in this area were offered.

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Chapter 1

INTRODUCTION

Purpose of the Study

The purpose of this study was twofold: 1) to examine the differences between the on-hand side and off-hand side spikes in volleyball in terms of velocity and accuracy, and 2) to evaluate the relationship of the angle of projection with velocity in each spike.

Significance of the Problem

Matsudaira (1977a) characterized the tendency of international volleyball playing development as follows: The Soviet Team depended upon power; the East German Team errorless play; the Czechoslovakian Team individual skills; the Romanian Team emotion; the Korean Team speed; the Cuban Team jumping ability; the Bulgarian Team strength; and the Japanese Team a quick combination attack and team work. Due to the recent numerous international competitions and exchanging of experiences and ideals by top volleyball countries, the philosophies and styles of play of these countries have been altered. One style of play is now characteristic of international competition. The present method of playing volleyball is often referred to as 'power volleyball' (Thigpen, 1969; Slaymaker & Brown, 1976; Scates, 1972). It emphasizes the use of strength and force in executing many of the game's skills. Spiking, blocking, and serving are now the most emphasized techniques in offensive play. Matsudaira (1977b) and Prsala (1971) indicated that spiking, the most effective and powerful of the three techniques, is executed directly above the net with the spiker having complete control over hitting power and the direction of the spike. Blocking, on the

other hand, involves an indirect attack which depends on the power and direction of the spiked ball from the opponent. Although serving is a direct offensive technique, the server is restricted to the serving area which is at least 9 metres away from the net. This allows the opponent enough time to predict and partially track the course of the ball.

In modern games, monotonous attacks are not effective against strong teams. Changes of speed, direction, and skill variety are team characteristics which are required as much as are multiple attacks and attacks characterized by constantly changing player positions. In order to enhance the efficiency of attacks, most teams use a penetrating setter from the back line. The purpose of this offensive tactic is to provide constant attack opportunities for the three front line players. In general, the position at the net of the penetrating setter will be between the right forward and center forward players. This has resulted in emphasis upon an on-hand side attack.

Preferably, an effective player should spike from the on-hand side and off-hand side with equal accuracy and power. However, Scates (1972) indicated:

An "on-hand" spiker can hit the line shot with greater accuracy and power than an "off-hand" spiker. (p. 128)

Walters and O'Hara (1969) referred to the on-hand side as being the strong side and the off-hand side being the weak side. They also noticed:

Championship players can hit almost as effectively from their weak side as from their strong side.

The ideal would be for a spiker to be ambidextrous, but this seldom happens. (p. 72)

This kind of advice has resulted in the majority of attack combinations taking place on the on-hand side with the concomitant result that opponents pay less attention to defending the off-hand side attack. Both these statements were based on the authors' opinions rather than substantiated facts. Because of the importance of the spike to the game of volleyball, a means of evaluating a player's proficiency in exerting these skills is necessary in the coaching situation.

This study used cinematography and direct recording methods to generate velocity, angle of projection, and accuracy data of the on-hand side and off-hand side spiked ball. A finding that there was no difference in the effectiveness of the two kinds of spikes could suggest changes in defensive and offensive tactics. For example, the frequency of attack from the on-hand and off-hand side would become more similar resulting in increased difficulty for the opponent in defensive play. If differences were observed then the use of each skill could be more appropriately described to enhance the strengths of each.

The results of this study will provide information for players and coaches. It will clarify an unclear aspect of the game of volleyball.

Delimitations

- 1) The subjects were 12 varsity volleyball players from the University of Alberta.
- 2) The ability to spike effectively was evaluated in terms of velocity, accuracy, and angle of projection of a spiked ball.

3) A straight spike was performed from a straight approach and was the only variation of the spike examined.

4) A regulated, mechanical center set was used for the spiking trials.

5) The best balls available were used. However, they were not new balls, and the air pressure of the balls may have varied slightly.

6) The testing was conducted on an indoor regulation volleyball court over a one day period.

Limitations

1) The ball setting action produced a consistent presentation which served to reduce the variability of each player's action.

2) A maximum of 20 trials for each subject from the on-hand side and off-hand side was assumed to produce consistent performance.

3) Five trials were assumed to be sufficient to reach a maximum level of performance (warm-up effect).

4) It was assumed that each subject exerted a maximal effort on each trial.

5) It was assumed that a spiked ball which landed in the 6 or 7 point target area was produced by a consistent spiking technique within each subject.

6) For statistical purposes, an alpha level of .05 was set more because of convention than any other reason.

Definitions

1) Straight spike is a spike where the ball is hit into the opponent's court along a path which is at a right angle to the net.

2) Straight approach is an approach where the spiker advances

toward the net along a path which is at a right angle to the net.

3) On-hand side spike is a spike which is executed from a set approaching the spiker from the same side as the spiker's hitting hand (Schaafsma & Heck, 1971).

4) Off-hand side spike is a spike which is executed from a set approaching the spiker from the side of the spiker's non-spiking hand (Schaafsma & Heck, 1971).

5) Regular center set is a set that is aimed at the center of the court and is characterized by a parabolic flight path with a peak approximately 1.86 m above the net.

6) Angle of projection is the angle, in the vertical plane, made by the path of the ball to the horizontal plane in the initial section of the ball's flight.

7) Velocity refers to the speed of the ball and is expressed in m/sec.

8) Accuracy is a measure of the ability of a player to direct the ball to a designated target.

Chapter 2

REVIEW OF LITERATURE

In volleyball there is much discussion regarding the on-hand and off-hand spikes and special defensive manuevers are employed because of them. However, there is a deficiency of scientific research in volleyball regarding the comparison of the on-hand and off-hand offensive techniques.

On-hand and Off-hand Side Spikes

Shondell and McManama (1971), Scates (1972), Selznick (1973), and Tennant (1975) referred to the on-hand side as the strong side and to the off-hand side as the weak side. Schaafsma and Heck (1971) indicated that the off-hand down-the-line spike was more difficult to perform than the on-hand down-the-line spike because the spiker must wait for the set ball to travel the extra distance across his body before contacting it. Due to the above timing and position problems, Schaafsma and Heck (1971) suggested that beginning level setters set the on-hand spike more frequently than the off-hand spike. In analyzing the movement pattern for the off-hand spiker, they stated:

. . . the amount of power producing shoulder rotation is limited by the need to look the opposite direction from the shoulder in order to watch the ball. (p. 43)

Scates (1972) also indicated that with the on-hand form a spiker could hit a line shot with greater power and accuracy than when executing an off-hand spike. Scates (1972) and Benson (1974a) stated that most of the teams set to the on-hand spikers more often than the off-hand spikers. For this reason, Scates and Benson (1974b) suggested that

the two most effective and strongest blockers should be switched to the power side against the on-hand spiker. The above statements were based on the authors' opinions rather than substantiated facts. It appears that practitioners recognize the on-hand spike as having "better qualities" than the off-hand spike in offensive volleyball.

Hunebelle, Peeters, Pieron and Samson (1977) observed and compared the results of the final matches between the Japanese and Soviet women's teams in Munich and the Montreal Olympic Games. In the location attack patterns they reported that both teams had a significantly higher percentage of attack at the left forward (on-hand) than at the right forward (off-hand) position on two occasions. The left forward attack percentage of the Japanese (43.3%, 47.4%) and the Russians (53.4%, 47.5%) compared to the right forward attack percentage (35.5%, 15.3% and 27.2%, 31.9% respectively) revealed that both these top level teams emphasized on-hand side attack combinations.

Velocity

Several researchers measured the velocity of the spiked ball to emphasize the use of strength and power in executing the spike. McCloy (1948) measured the speed of the spiked ball at the National AAU Volleyball Tournament in the United States. He reported a mean velocity of 91 ft/sec (62 mph) and a maximum velocity of 162 ft/sec (110 mph). Nelson (1964), in a similar investigation to that done by McCloy, filmed the spikes of eight skilled male players from the best team competing at the National Volleyball Tournament in the United States. The subjects were instructed to spike the ball at a right angle across the net. The ball was set for spiking trials by a setter in the center of the court at the net. If the trial involved an improper set or

spike, the trial was repeated. Nelson found an average velocity of 76.6 ft/sec and a maximum velocity of 99.3 ft/sec. The velocities that he reported were considerably lower than McCloy's. Nelson concluded: a) that neither McCloy's nor his study was in error, b) that both studies were correct in analyzing the different velocities of the spiked ball, and c) that the players tested in 1948 were better than those tested in 1961.

In a one female subject experimental design, Webster (1970) studied the effect of the straight approach and the angular approach spikes in terms of velocity of the spiked ball. She observed a female spiker performing 10 trials for each type of spike on five different days. For consistency through trials, a stationary ball was placed in position between two constructed tongs. The elapsed time from ball spike contact to floor contact was measured by a noise-operated relay and Hunter Klockcounter. The distance that the ball travelled was determined by trigonometric procedures. The velocity of each spiked ball was computed by using the formula $V = \frac{d}{t}$. No significant differences in ball velocity for the angles of approach were reported.

Spike Assessment

Since the spike is such an important skill in the game an evaluation of its effectiveness is necessary for teaching and for coaching situations. Rogers (1969) indicated that the velocity and the angle of projection of the spiked ball were two of the fundamental components which determined the effectiveness of the spike. Slaymaker and Brown (1976) suggested that when evaluating the effectiveness of the spike, speed, downward angle, and placement of the ball should be considered.

No available literature indicated a generally accepted area of the court as the best placement for the spiked ball. Blackman (1968) selected an in-court hit as an accuracy criterion in the development of a skill test for the spike. Cherebetiu (1969) indicated that the variety and efficiency of the offensive play depends on the opponent's tactics and weaknesses. Laveaga (1960) suggested a spike test based upon the principle that the ball should be placed in the least protected area.

Blackman (1968) studied the spike by means of the velocity and the angle of projection of the spiked ball in order to evaluate the performance of female students. In this study 70 students in a volleyball service class and 11 volleyball club members at Southern Illinois University served as subjects. Two scoring systems were devised by dividing the court into at first 9 and then 12 areas. A spiked ball landing in an area was assigned points according to its velocity and its angle of projection. The on-hand spike was the only variation of the spikes studied. A low correlation between velocity and angle of projection was reported. This indicated that different elements of the spike were being measured. Blackman also concluded that the effectiveness of a spike may be determined by measuring the velocity, the angle of projection, and the accuracy of the spiked ball.

In summary, the limited available literature revealed that the on-hand side is referred to as the strong side, while the off-hand side is referred to as the weak side. Attack combinations emphasize the on-hand side because supposedly the on-hand spiker can hit the ball with greater velocity and accuracy than can be achieved from the off-hand side. In evaluating the effectiveness of a spike, velocity, accuracy

and the angle of projection of the spiked ball should be considered.

Chapter 3

METHODS AND PROCEDURES

Subjects

Twelve male varsity volleyball players from the University of Alberta, ranging in ages from 18 to 33, served as subjects. Eleven players were classified as a national level and one as an international level athlete. Their physical characteristics and volleyball history are tabulated in Appendix A.

Testing Location and Time

The testing procedures took place in the Education Gymnasium at the University of Alberta on October 31, 1979 from 5:00 p.m. to 7:00 p.m.

Equipment and Facilities

A high speed Photo Sonic #P1-16 mm motion picture camera, containing an internal electronic timing device, loaded with EKTACHROME 7250 color film with an ASA rating of 400, was used for filming. The tripod mounted camera was placed on a table top located on the extended center line of the court 9.50 m from the center of the spike control area. The height of the camera from the tripod to the floor was 2.60 m. The camera speed and f-stop were set at 60 f/sec and 2.2 respectively. The natural light of the gymnasium was used. A scaled stick was filmed above the center line of the control area at the height that the ball would be hit. This served as the calibration unit for determining linear measurements.

A machine which simulated a center set was built in order to standardize the delivery of the ball. The device is shown in Figure 1. Descriptions of its construction and reliability are contained in Appendix B.

Testing was conducted on an indoor standard volleyball court, and

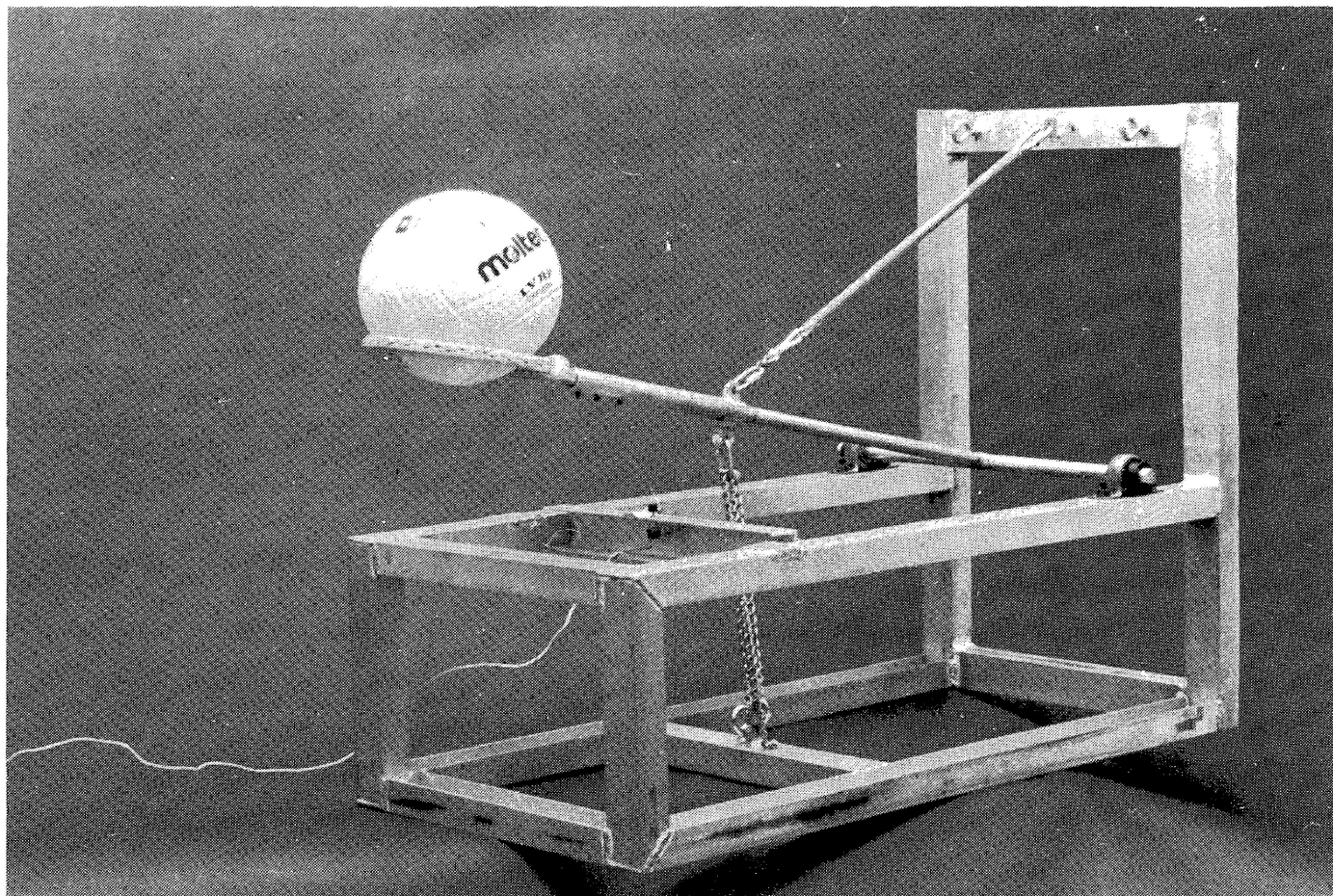


FIGURE 1
BALL SETTING MACHINE

the net was set at a height of 2.43 m. A straight spike control area and straight approach control area were marked off by two .635 cm ropes taped on the floor one meter apart from each other as shown in Figure 2. The purpose of these control areas was to restrict the subjects to the use of the straight spike approach and accuracy.

The straight spike control area was also marked off with .635 cm ropes in rectangles which served as a target for evaluating the accuracy of each spike. The center point of the target was located 6 m from the center line of the court and was between the boundaries of the straight control area. The divisions were marked off in increments of 50 cm between the attack line and end line. The center area of the target represented the highest accuracy target and was assigned the highest value of seven points. The two areas adjacent to the center area were assigned a value of six points. Subsequent areas were reduced by one point in descending order. A spike which landed in the spike control area earned a minimum of one, and a maximum of seven, points. A spike which landed outside the area earned no points.

In order to simulate the height of a setter when setting a ball, the setting machine was placed on a 1.24 m high vaulting box. The frame of the machine was .31 m in depth and the point of release a similar distance above that. The height of release of the set ball was 1.86 m.

When a subject performed an on-hand side spike, the machine was located on the preferred hand side at the net, 1.829 m away from the center line of the approach control area. The machine was relocated at 2.13m, but on the non-preferred hand side for the off-hand spike trials.

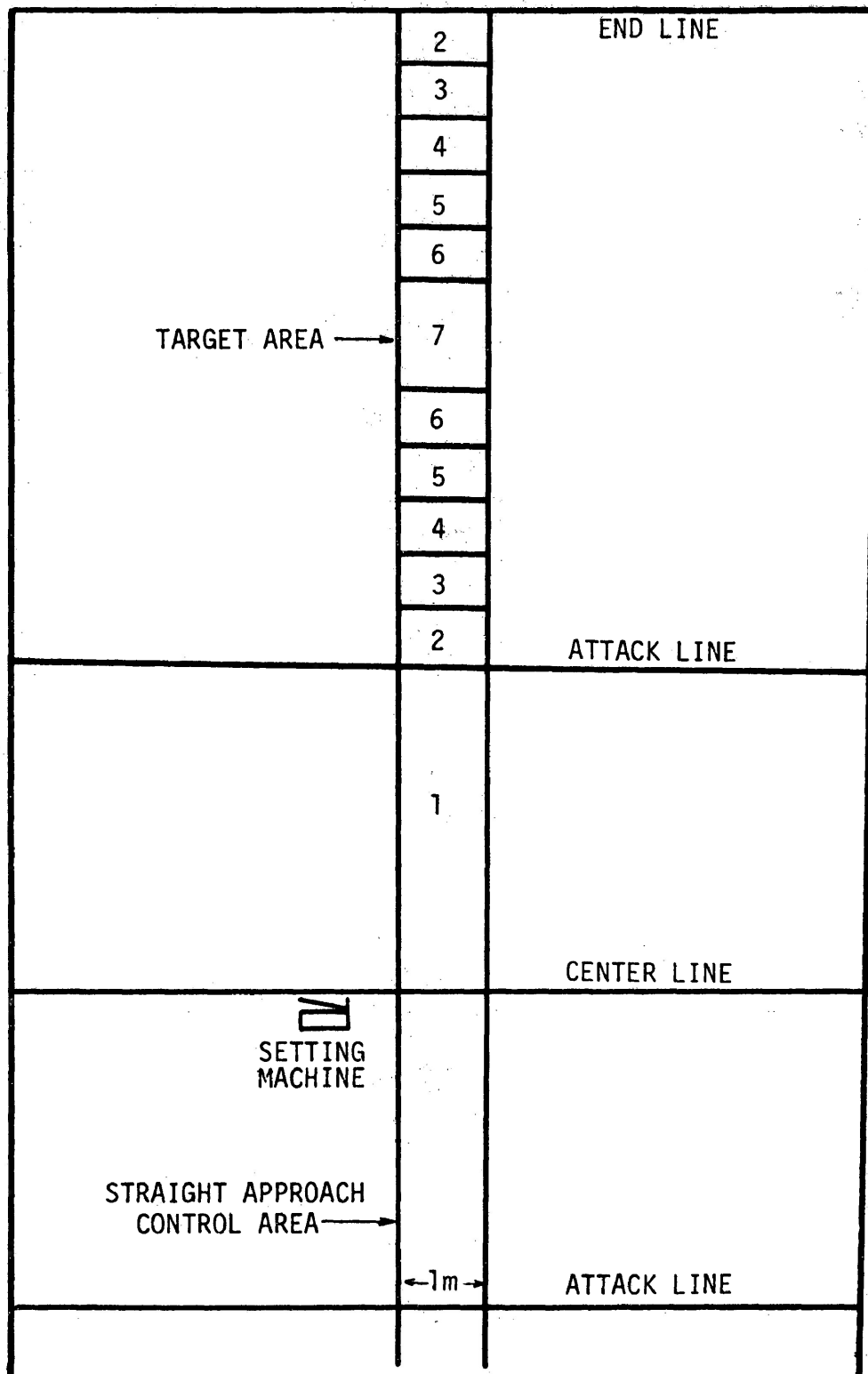


Figure 2. Test location and target area.

Research Design and Method

This study used a repeated measures design. Data for velocity and angle of projection of both spiking techniques were obtained by filming. Accuracy scores were recorded directly after each trial. Session 1 consisted of gathering data for on-hand spikes for right-handed players and off-hand spikes for left-handed players. In session 2, the data for the other spikes were gathered. In both sessions subjects were filmed from the sixth to the twentieth trials inclusively in order to determine an accuracy score. Because the velocity analysis was dependent upon the ball landing in a specified target area retrials were given to each subject until at least eight valid accuracy scores were obtained (see scoring sheet in Appendix D).

Test Description and Procedures

The spiking test was conducted in a non-blocking practice situation. Scores were obtained for two treatment variables - the on-hand side and off-hand side spikes. Each subject was required to perform at least 20 trials for both activities. Spiking orders were randomly assigned to the subjects. The subject order of performance was replicated across all trials. Each spike was executed on a ball which was set by the ball setting machine. All subjects were required to use a straight approach within the stipulated control area and spike the set ball into the target area of the opponent's court. No point was awarded for any trial where (a) the ball did not land within the target area, (b) the player committed a spiking foul infraction, or (c) the ball struck the net before landing in the target area. In such cases a retrail was ordered but only velocity and angle data were recorded. The original zero score for accuracy remained as part of the total accuracy score. The scorer,

photographer and the ball setting machine operator were the only individuals other than the subjects present during testing. The scorer indicated the trial number. He was also responsible for calling the subjects to the test area and recording the scores on a prepared form (see Appendix D). A command of "ready, set" was used by the machine controller for every trial. The throwing arm of the machine was released simultaneously with the word "set".

Cinematographical Analysis

A Bendix Digitizer (Model 2425520) in conjunction with a computer (Hewlett Packard 9825A) and electrical printer (Hewlett Packard 9871A) were used to quantify data points from the films. The projected film was kept at a constant distance and the height from the digitizer during the analysis. The second and third frame of the spiked ball in flight after the contact had disengaged were used for analysis. The film rate was 1 frame per .0167 seconds. This was determined by the flash spots on the edges of the film made by an internal electronic timing device in the camera. A computer program was written to compute the velocity and angle of projection of the spiked balls. One computer velocity unit was equal to 5.46 m/sec. This was calibrated by using the scale stick filmed prior to testing. Data gathering from the film was doubled checked by a second party.

Statistical Analysis

1. Velocity. The average of the first eight valid trials for both the on-hand and off-hand spikes of each subject was used for statistical analysis. A correlated t test was performed. An alpha level of .05 was established for significance.

2. Accuracy. The accuracy measures for each trial, sixth through twentieth, were accumulated to produce an accuracy score for each spiker. These totalled scores were then analyzed using a correlated t test with an alpha level of .05.

3. The interaction of angle of projection with velocity. The velocity and angle of projection of all trials for both spiking techniques of each subject were used for statistical analysis. A Pearson Product-moment Correlation Coefficient was calculated to analyze the relationship between the two variables for each subject. Then, the resulting correlation coefficients for both spiking methods for all the subjects were compared using a correlated t test. An alpha level of .05 was set for significance.

Analyses were first computed manually and then verified using the Statistical Package for Social Sciences (Nie, Hull, Jenkins, Steinbrenner & Bent, 1975) computer programs.

Chapter 4

RESULTS

Accuracy

The correlated t test comparing accuracy scores for the on-hand ($\bar{X}=68.9167$) and off-hand ($\bar{X}=59.0837$) spikes was significant at the .05 level ($t=2.92$, $df=11$). This indicated that the on-hand spike was more accurate, in terms of hitting a specified target, than the off-hand spike (see Table 1).

Velocity

The correlated t test comparing velocity scores for the on-hand ($\bar{X}=3.9626$) and off-hand ($\bar{X}=3.7772$) spikes was significant at the .05 level ($t=3.58$, $df=11$). The velocity figures shown in parentheses are expressed in computer units. One computer unit was equal to 5.46 m/sec. Thus, the average velocities for both on-hand and off-hand spikes were 21.6358 m/sec and 20.6235 m/sec respectively. This indicated that the on-hand spike was performed with greater velocity than the off-hand spike (see Table 2).

Angle of Projection and Velocity

The angle of projection and velocity of each spike for both the on-hand and off-hand forms was determined. A Pearson Product-moment Correlation Coefficient for the two variables was calculated for both spikes for each subject. Three of twelve relationships were low but significant for the off-hand spike, while only one of twelve was significant for the on-hand spike.

What was surprising in these data was the occurrence of negative relationships. For the on-hand spike four of the twelve relationships,

Table 1
 Matched Pairs t Test for Accuracy Scores Between
 the On-hand and Off-hand Spikes for Each Subject.

Subject	On-hand Spike	Off-hand Spike
1	54	26
2	94	66
3	60	57
4	75	65
5	71	68
6	57	49
7	69	54
8	64	56
9	63	66
10	68	62
11	76	71
12	76	69
N=12	$\bar{X}=68.9167$ SD=10.7658	$\bar{X}=59.0837$ SD=12.4130

Note. Maximum accuracy score = 105
 $df=11$, $t=2.92$, $P < .05$

Table 2
 Matched Pairs t Test for Velocity Data between the
 On-hand and Off-hand Spikes for Each Subject.

Subject	On-hand Spike	Off-hand Spike
1	3.2613	3.1388
2	3.6286	3.8566
3	3.6567	3.3942
4	3.9995	3.9286
5	4.3734	4.0755
6	4.0258	3.7664
7	3.7690	3.3901
8	4.2782	4.0417
9	4.3727	4.0712
10	4.1766	4.1162
11	4.1846	4.3042
12	3.8249	3.2432
N=12	$\bar{X}=3.9626$ SD= .3425	$\bar{X}=3.7772$ SD= .3881

Note. $df=11$, $t=3.58$, $P < .05$

One computer unit was equal to the velocity of 5.46 m/sec.

although non-significant, were negative while one such instance was indicated for the off-hand spike (see Table 3). Considerable variations of relationships were exhibited between subjects.

When all data for each subject were pooled for each spike the on-hand spike ($r=.0842$, $df=151$) revealed a non-significant relationship, while the off-hand ($r=.3666$, $df=170$) indicated significance at the .05 level.

This finding is somewhat confusing. Individual analyses generally indicated independence between the two factors for each spike. However, the pooled data supported independence for the on-hand spike but dependence for the off-hand spike.

A correlated t test comparing the average correlation coefficients for the on-hand ($\bar{X}=.0723$) and off-hand ($\bar{X}=.3420$) spikes was not significant at the .05 level ($t=-2.16$). This indicated that there was no statistically significant difference between whatever relationship existed for either spike.

The t test which yielded non-significance between the two is sufficient to suggest that the size of the relationships for each spike form was not large enough to warrant different interpretations. Thus, it was concluded that, generally, there is no relationship between velocity and angle of projection in straight spiking in volleyball for either form of spiking.

The individual raw data, mean and standard deviation of velocity, accuracy and angle of projection for both the spiking techniques are presented in Appendix E.

Table 3
 Matched Pairs t Test for Correlations Between Velocity
 and Angle of Projection for the On-hand and Off-hand
 Spikes for each Subject.

Subjects	On-hand Spike \bar{r}	Spike df	Off-hand Spike \bar{r}	Spike df
1	-.2045	8	.4384	8
2	.4705	13	.5117	11
3	.1151	10	.0472	12
4	-.3814	13	.6475 ^a	10
5	.3202	12	.2656	10
6	-.4910	8	-.0571	15
7	.1735	12	.6227 ^a	13
8	-.2713	9	.3519	16
9	.0055	11	.3850	16
10	.0579	11	.5527 ^a	13
11	.7461 ^a	11	.3103	12
12	.3265	11	.0283	12
N=12	\bar{X} =.0723		\bar{X} =.3420	

Note. $df=11$, $t=-2.16$, $P > .05$

Chapter 5

DISCUSSION

The spike plays an important role in modern volleyball. The straight spike is one of the fundamental techniques in offensive play. Although the on-hand spiker and the off-hand spiker have similar movement patterns in performing the straight spike technique the off-hand spike is supposedly more difficult. It is proposed that this is due to the fact that the spiker must wait for the set ball to cross his body before contacting it (Schaafsma & Heck, 1971). The on-hand spiker does not have this timing problem. Schaafsma and Heck (1971) also stated that the off-hand spiker's power was limited because shoulder rotation was restricted by the need to watch the set ball coming from the opposite direction. The analysis of the movement problem is not within the scope of this study, but it is worthy of consideration when attempting to explain differences between the on-hand and off-hand spikes.

Data analysis for the purpose of comparison of the on-hand and off-hand techniques revealed that the mean velocities were 21.6358 m/sec and 20.6235 m/sec and the mean accuracy scores were 68.9167 and 59.0837 respectively. A correlated t test comparing the velocities and accuracy scores for the on-hand and off-hand spikes were significantly different at the .05 level. Results indicated that on-hand spikes were hit with greater velocity and accuracy than the off-hand spikes. The data showed that all subjects with the exception of subject 9 performed the on-hand spike with greater accuracy (see Table 1). This exception may have been due to special training or an individual hitting habit. The mean velocities for similarly accurate trials showed that 10 of the 12 subjects

performed the on-hand spike with greater velocity than the off-hand spike (see Table 2). However, when the velocities for all trials, irrespective of how accurate, were considered, the mean velocity for the on-hand spike was, for all subjects, greater than that of the off-hand spike (see Appendix E). This conclusion fully supported Scates's (1972) statement that:

An "on-hand" spiker can hit the line shot with greater accuracy and power than an "off-hand" spiker. (p. 128)

These results also verified the opinions of Schaafsma and Heck (1971), Shondell and McManama (1971), Selznick (1973), and Tennant (1975). However the data of this study disagreed with Walters and O'Hara's (1969) comment that:

Championship players can hit almost as effectively from their weak side as from their strong side. (p. 72)

In this study, the interaction between velocity and angle of projection of the on-hand spike was found to be non-significant. However, the interaction between the velocity and angle of projection for the off-hand spike indicated a significant but low correlation.

Blackman (1968) found a low correlation between the velocity and angle of projection of the on-hand spike. Her subjects were female and of a different skill level to the subjects used in this present study. These factors may have accounted for the conflicting findings of the two studies. This is possible, if one assumes that the present subjects' off-hand techniques were not as highly developed in terms of skill level when compared to the on-hand spike, possibly because of more

practice, preferred use, etc., then it could be reasonable to assert that in lower-skilled spikes the factors of velocity and angle of projection are related. This deduction is supported by Blackman's findings where the subjects were of a lower skill classification than those used by this author.

There is a possibility that Blackman's (1968) conclusion that different qualities of the spike were being measured, might also apply to this study. An interesting and unexpected finding in the analysis was that 10 of the 12 subjects performed the off-hand spikes with greater downward angle than the on-hand spikes. Subjects 2 and 4, both left handers, were the exceptions. Generally, the data indicated that in the on-hand spike, the greater the velocity the smaller the downward angle, but in the off-hand spike, the greater the velocity the larger the downward angle. This relationship could explain why the on-hand spike correlation between velocity and downward angle was not significant, while the correlation between the off-hand spike velocity and downward angle was.

Although the results obtained from the national and international level male athletes in this study could possibly be generalized to similar calibre male university teams, there would be a danger in generalizing these results to other groups of volleyball players. Differences in variables such as strength and skill level might yield entirely different results. Further studies need to be conducted to determine the universality of these findings, particularly along the dimension of levels of skill technique.

The testing of this study was conducted in a non-blocking situation. The subjects were not confronted with an opponent's tall and aggressive

blockers and other defensive personnel working against them. Under such defenceless conditions, and the arc and timing of the set ball being standardized by the machine, the performance of the spikers, in terms of accuracy and velocity, would probably be better than those in a game situation. Some future consideration should be given to assessing whether the revelations of this arbitrary laboratory setting also exist in the circumstances of a game.

The success of a spike is not measured by the velocity of the ball but by counting the point won or lost as a result of the action. Therefore, the accuracy and displacement of the spiked ball are vital for game success. In this study, the average angle of projection of the spiked balls might have been greater than those exhibited in a game situation. In a contest, the spiker would probably contact the set ball as high as possible and lessen the downward angle in order to spike over the interference of the opponent's blockers.

The purpose of the warm-up assumption in this investigation was to stabilize performance and to facilitate maximum effort. Although variation existed between trials, the data revealed that the variability of each subject was relatively symmetrical about the mean and spread along the data stream. This symmetry indicated that subjects' performances were stable. Generally the variability of the last two trials were similar to the variability of the first two trials. It is contended that the five trials warm-up accomplished its purpose.

The results obtained in this study suggest that a coach would be well advised to put more confidence in the on-hand attack than the off-hand attack. It would seem advantageous to design defences with these facts in mind. Efficiency might be increased by setting more

frequently to the on-hand spiker than the off-hand spiker. An advantage might be gained by switching or substituting when appropriate, a right-handed player for a left-handed player in the left forward position, or conversely, a left-handed spiker for a right-hander in the right forward position. This switching or substitution tactic probably would increase offensive spiking balance from both sides of the court. This tactic would also increase the defensive difficulty for the opponent.

Because this study revealed a significant difference in effectiveness between the two spiking techniques and because the reviewed literature indicated that opponents pay less defensive attention to the off-hand spiker, coaches may well be advised to spend more time working with the athletes to improve the off-hand spiking technique. Spiking diagonally or using an alternative form of approach when performing the off-hand spike, might improve the potency as an offensive weapon. There is also a possible simple explanation for the differences between on-hand and off-hand spikes. Assumedly the on-hand spike is easier than the off-hand action. It would, therefore, provide more readily available successes. Thus, the easier more accessible enforcement would encourage the practice and use of the on-hand action over the slightly more difficult off-hand action. It could be speculated that players are at higher levels of skill in the on-hand spike because of its greater practice and emphasis in training and competition than the level attained for the lesser preferred off-hand spike. This could account for observed differences.

The results for the on-hand spike differed from those obtained by Nelson (1964). The mean velocity of Nelson's study was 23.3172 m/sec

compared to 21.6347 m/sec for this study. However, the maximum velocity observed by Nelson was 30.2514 m/sec which was slightly less than the 31.2110 m/sec exhibited in this study. These differences in results are probably attributable to the facts that: a) Nelson measured eight of the United States' best national tournament players in 1961, b) this present study measured 12 of the Canadian varsity volleyball players in 1979, and c) Nelson's controls for setting and accuracy measurements were not as stringent as those employed in this investigation.

For this study, in order to control any possible series effect, it was proposed to use a balanced design over a two day testing period. However, an abrupt change in the participating team's schedule necessitated taking all measurements on the same day. Unfortunately, because of the time factor the balanced design was not able to be employed. Consequently measurements were taken with all 12 subjects performing, when the ball was set first from the right side for a full block of trials and then from the left side for the remaining trials. Because two of the subjects were left-handed, this resulted in 10 players performing all trials for the on-hand techniques first and the two players performing all trials for the off-hand technique first. This change in design might have introduced possible series effects. Any further study should consider employing a balanced design and controlling the time factor involved in the testing period.

Future studies should also consider varying the angle of approach to the spikes, using different skill level subjects, and using different sex players in the samples. The picture about the two forms of spiking is still unclear and further research is warranted to

clarify the significant determinants and characteristics of this offensive volleyball skill.

Chapter 6

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The main purpose of this study was to examine the effects of the on-hand and off-hand spikes in terms of accuracy and velocity. A secondary purpose was to investigate the interaction of the angle of projection and the velocity of a spike between these two techniques in volleyball.

The University of Alberta's male varsity volleyball team, consisting of one international and eleven national level players, served as the subjects for this study.

The research design employed a repeated measures technique with two variables, the on-hand and off-hand spikes. The subjects were required to perform 20 straight spikes for each technique. The velocity and the angle of projection data for each trial were obtained by cinematographical analysis. Accuracy scores were collected by direct recording after each trial.

A correlated t test was used to determine the differences in velocity and accuracy between the on-hand and the off-hand spikes. A Pearson Product-moment Correlation Coefficient was used to assess the relationship between the velocity and the angle of projection of each spiking technique for each subject. A further correlated t test was used to determine differences in that relationship between the on-hand and off-hand spikes.

Conclusions

Based on the results of this investigation, it was concluded that:

1. In the straight spike, the on-hand spike was more accurate than the off-hand spike.
2. In the straight spike, the on-hand spike produced a greater ball velocity than the off-hand spike.
3. There was no relationship between the velocity and the angle of projection in the on-hand straight spike but a low relationship between the two was observed for the off-hand spike.
4. The size of the relationship between the velocity and angle of projection was not significantly different between the on-hand and off-hand spikes.

Recommendations

1. Future studies should be done with different types of approaches used for both spiking techniques.
2. Players of both sexes and different skill levels should be compared under controlled conditions.
3. A balanced design to control any possible series effect should be considered in any future investigation.

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APPENDIX A
PHYSICAL CHARACTERISTICS OF THE SUBJECTS

APPENDIX A

PHYSICAL CHARACTERISTICS OF THE SUBJECTS

N=12	Age (Years)	Height (cm)	Weight (kg)
range	18-33	178-191	70-86
mean	21	185.92	79.79
S.D.	3.9312	5.8498	5.2374

PHYSICAL CHARACTERISTICS AND VOLLEYBALL HISTORY OF THE SUBJECTS

Subject	Predominant Hand	Age	Height (cm)	Weight (kg)	Experience (years)	Skill Level
1	Right	20	179	80	8	National
2	Left	18	185.5	81.5	5	National
3	Right	22	183	77	9	National
4	Left	19	188	81.5	7	National
5	Right	20	188	82	7	National
6	Right	21	178	70	5	National
7	Right	20	198	86	7	National
8	Right	19	191	86	7	National
9	Right	21	188	86	7	National
10	Right	20	178	75.5	5	National
11	Right	19	189	79.5	8	International
12	Right	33	185.5	72.5	6	National

APPENDIX B
CONSTRUCTION AND RELIABILITY
OF THE BALL SETTING MACHINE

APPENDIX B

Construction of the Machine

The ball setting machine was designed to duplicate a regular center set for the spiking trials. The flight of the ball was a free fall motion having a path which was parabolic in shape. It was necessary to design a machine which would standardize this center set.

Duplication of the path of the set ball was accomplished through the use of a lever system designed as a catapult. The force required for activating the throwing arm was generated by releasing a lengthened spring attached to the frame and lever arm. Rotation of the throwing arm was stopped at an angle of projection of 76 degrees to the vertical by a chain attached to the lever and the base of the frame.

Basically, this device consisted of a 91.44 cm x 30.48 cm x 95.72 cm metal frame upon which a 91.44 cm long lever was attached to a cross bar by means of a pair of bearings. A modified frame of a squash racquet attached to the lever was used to hold the ball in place until projected into the air. A string was used to narrow the space of the racquet face, thus permitting the ball to sit steadily in the racquet before the flight. The machine is shown in Figure 1.

Reliability of the Machine

Cinematographical analysis was used to test the reliability of the ball setting machine. In order to obtain displacement data for the set ball at the same instant after it had begun its flight, an electrical timing mechanism unit was constructed. This mechanism triggered an electronic flash gun after a pre-set time, thereby taking a picture of the ball in flight. This device was governed by a variable resistor

setting. The electrical wiring diagram is shown in Appendix C. The time could be adjusted to any value in the range of .5 seconds to 3 seconds. A switch which activated the timer was installed under the throwing arm of the machine.

The testing procedure took place in a darkened room in the gymnasium at Lakehead University. The ball setting machine and a large black board with vertical scales at each end were placed on the floor against a wall such that the flight of the set ball described a path in front of the black board. A camera (Minolta XD7 with 1.4 lens) was fixed on a tripod. The tripod, a flash gun and an electrical timer were positioned on a 1.25 m high table facing the black board. The camera was adjusted to 1.7 m from the floor and 2.5 m from the black board. The set ball passed in front of the camera when the timer triggered a flash.

In the testing situation the room was darkened and the camera shutter opened. The flash was activated at a preset time after the ball setting machine controller released the throwing arm. The image of the set ball was recorded when the flash occurred. The camera shutter was then closed. The same procedures and settings were used for a test and retest session conducted on two different days. Twenty trials on both days were recorded.

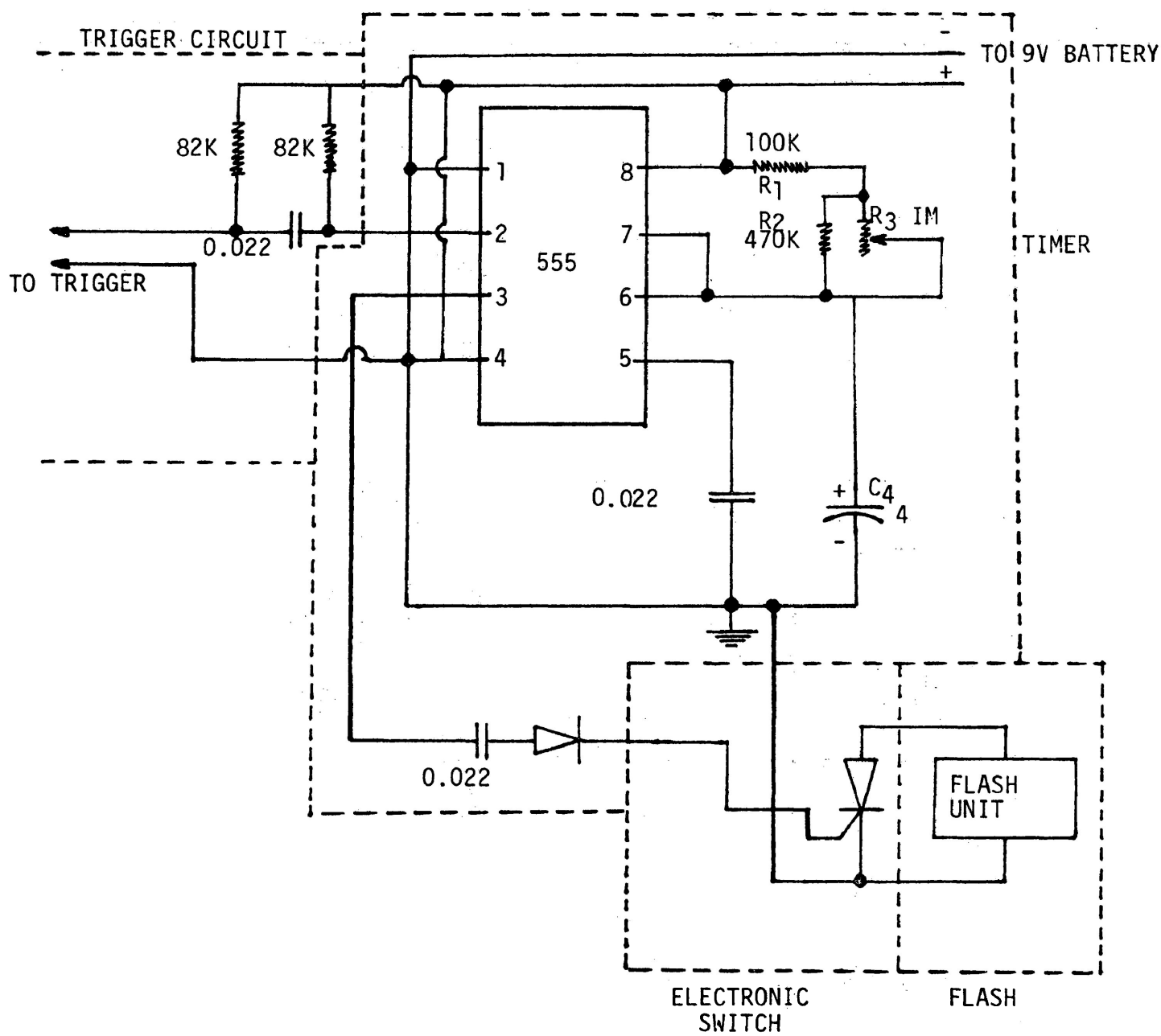
A Kodak slide projector was used for viewing the slides. It was placed on a table which was at a set distance from the wall. A white surface was positioned on the wall. A clear image was focused onto the projection surface. The displacement of the ball was measured from the projected image. A Pearson Product-Moment Correlation Coefficient was determined to relate the test and retest scores as a measurement of

reliability. The correlation coefficients for both the horizontal and vertical displacement of the set balls were $r=.9215$ and $r=.9136$ respectively. Both statistics were statistically significant at the .05 level with 8 degrees of freedom indicating that the machine's performance was reliable.

APPENDIX C
ELECTRICAL DIAGRAM OF THE FLASH TIMER

APPENDIX C

ELECTRICAL DIAGRAM OF THE FLASH TIMER



APPENDIX D
ACCURACY RECORDING FORM

APPENDIX E
SUBJECTS' RAW DATA

TABLE A
Subject 1 On-hand Raw Data

Trial	Velocity	Angle	Accuracy
6	—	—	0
7	3.2735	-22.0737	7
8	3.3862	-19.7839	6
9	3.2591	-20.9821	6
10	3.2942	-20.1646	6
11	—	—	0
12	—	—	0
13	—	—	0
14	3.1262	-20.6539	6
15	—	—	0
16	2.9679	-19.5993	6
17	3.5282	-16.6226	3
18	3.3931	-19.5468	6
19	3.3452	-20.9908	6
20	3.1872	-16.3678	2
N=10	$\bar{X}=3.2761$ SD= .1564	$\bar{X}=-19.6786$ SD=1.8463	$\Sigma =54$

TABLE B
Subject 2 On-hand Raw Data

Trial	Velocity	Angle	Accuracy
6	4.1460	-39.9401	1
7	3.8575	-20.8636	5
8	3.3913	-23.8059	7
9	3.4970	-22.7732	7
10	3.6236	-23.9354	7
11	3.4598	-24.9417	7
12	3.5943	-20.0452	6
13	3.9072	-24.3701	7
14	3.8047	-22.5670	7
15	3.7511	-24.1748	7
16	3.5605	-20.9831	6
17	3.8285	-23.4078	7
18	4.0482	-23.0007	7
19	3.4937	-21.9867	6
20	4.0662	-23.5926	7
N=15	$\bar{X}=3.7353$ SD= .4200	$\bar{X}=-24.0259$ SD=4.6204	$\bar{X}=94$

TABLE C
Subject 3 On-hand Raw Data

Trial	Velocity	Angle	Accuracy
6	3.7062	-21.7014	6
7	—	—	0
8	3.6265	-20.5869	6
9	3.7455	-24.9373	7
10	3.8975	-26.6650	6
11	3.4969	-20.7257	6
12	3.3460	-17.4046	2
13	—	—	0
14	—	—	0
15	4.0690	-16.5037	2
16	3.1526	-23.2491	7
17	3.7003	-25.3544	7
18	3.6560	-16.2260	2
19	3.9281	-26.9469	6
20	3.7835	-18.1036	3
N=12	$\bar{X}=3.6757$ SD= .2528	$\bar{X}=-21.5337$ SD=3.9153	$\Sigma =60$

TABLE D
Subject 4 On-hand Raw Data

Trial	Velocity	Angle	Accuracy
6	4.1968	-26.4722	6
7	3.4583	-26.3124	6
8	3.7584	-30.9240	5
9	3.6405	-24.9590	7
10	4.3348	-25.2735	6
11	3.7017	-31.7309	4
12	3.4261	-32.4907	4
13	4.1094	-34.7488	3
14	3.6210	-31.9544	4
15	3.4235	-29.6273	4
16	5.2087	-22.6713	7
17	4.2580	-26.7481	6
18	3.3675	-25.9863	6
19	3.7381	-36.7246	1
20	3.5313	-27.1199	6
N=15	$\bar{X}=3.8516$ SD= .4945	$\bar{X}=-28.9162$ SD=4.2359	$\Sigma =75$

TABLE E
Subject 5 On-hand Raw Data

Trial	Velocity	Angle	Accuracy
6	4.6076	-29.9564	5
7	4.6082	-20.7222	6
8	4.6722	-31.8274	4
9	3.9308	-19.9073	6
10	4.4987	-16.9033	3
11	4.5789	-20.7961	6
12	4.9995	-19.8590	6
13	3.7037	-16.2645	2
14	3.9009	-24.1666	7
15	—	—	0
16	4.2531	-19.8606	6
17	4.1556	-19.5676	5
18	4.3268	-17.3327	3
19	4.6053	-20.2903	6
20	4.1104	-20.5809	6
N=14	$\bar{X}=4.3537$ SD= .3615	$\bar{X}=-21.2882$ SD=4.5202	$\Sigma =71$

TABLE F
Subject 6 On-Hand Raw Data

Trial	Velocity	Angle	Accuracy
6	3.1288	-23.6294	7
7	4.6125	-20.5257	6
8	—	—	0
9	—	—	0
10	—	—	0
11	5.1182	-18.4658	5
12	4.7084	-20.8579	6
13	3.9283	-23.1341	7
14	4.4031	-19.9142	6
15	—	—	0
16	3.8943	-20.0991	6
17	3.9840	-16.1423	2
18	—	—	0
19	3.8933	-20.9321	6
20	3.6378	-21.6240	6
N=10	$\bar{X}=4.1309$ SD= .5809	$\bar{X}=-20.5325$ SD=2.1585	$\Sigma=57$

TABLE G
Subject 7 On-hand Raw Data

Trial	Velocity	Angle	Accuracy
6	3.5128	-20.9627	6
7	4.2386	-23.3354	7
8	3.3237	-20.8545	6
9	3.2342	-21.8395	6
10	3.4501	-18.5014	4
11	4.8705	-20.4723	6
12	4.0179	-21.7200	6
13	—	—	0
14	3.9858	-17.5769	3
15	3.5425	-20.6136	6
16	3.7085	-17.4612	3
17	3.3818	-16.5855	2
18	3.2637	-18.2116	5
19	3.5084	-16.8194	2
20	3.4119	-23.7864	7
N=14	$\bar{X}=3.6750$ SD= .4580	$\bar{X}=-19.9100$ SD=2.3775	$\Sigma =69$

TABLE H
Subject 8 On-hand Raw Data

Trial	Velocity	Angle	Accuracy
6	4.2178	-20.0715	6
7	3.7510	-21.1543	6
8	4.0681	-23.1142	7
9	4.0517	-20.2036	6
10	4.9990	-23.6792	7
11	—	—	0
12	3.5849	-22.9752	6
13	—	—	0
14	4.1125	-24.3917	7
15	5.4403	-20.9685	6
16	3.6554	-20.4349	5
17	—	—	0
18	5.2065	-17.4166	2
19	4.3673	-21.6563	6
20	—	—	0
N=11	$\bar{X}=4.3140$ SD= .6323	$\bar{X}=-21.4605$ SD=1.9958	$\Sigma =64$

TABLE I
Subject 9 On-hand Raw Data

Trial	Velocity	Angle	Accuracy
6	3.9171	-31.1549	4
7	3.7818	-24.7158	7
8	4.1169	-17.6769	2
9	4.1228	-26.6995	6
10	3.9115	-16.5771	2
11	3.9285	-17.6145	3
12	4.8364	-27.1291	6
13	—	—	0
14	5.7163	-20.0743	6
15	3.9257	-21.6986	6
16	3.9103	-16.4146	2
17	—	—	0
18	3.9602	-24.9903	7
19	4.3964	-21.1871	6
20	4.2423	-21.6875	6
N=13	$\bar{X}=4.2128$ SD= .5310	$\bar{X}=-22.1246$ SD=4.5772	$\Sigma =63$

TABLE J
Subject 10 On-hand Raw Data

Trial	Velocity	Angle	Accuracy
6	3.9019	-24.2584	7
7	4.2929	-26.5651	6
8	3.8900	-23.4839	7
9	4.7697	-16.2135	2
10	4.0107	-25.2856	7
11	4.7740	-17.4720	3
12	—	—	0
13	4.8730	-30.1663	4
14	4.9493	-18.1247	4
15	3.6582	-20.6955	6
16	—	—	0
17	4.5398	-25.9454	6
18	4.5407	-20.1632	6
19	4.5787	-25.3733	6
20	2.9679	-18.5993	4
N=13	$\bar{X}=4.2882$ SD= .5761	$\bar{X}=-22.4882$ SD=4.2340	$\Sigma=68$

TABLE K
Subject 11 On-hand Raw Data

Trial	Velocity	Angle	Accuracy
6	4.1589	-26.4429	6
7	4.1482	-26.2714	6
8	3.8964	-23.4629	7
9	4.8031	-29.8124	5
10	3.7159	-24.6769	7
11	4.5308	-31.1287	4
12	4.2172	-26.5651	6
13	3.8333	-18.5068	5
14	—	—	0
15	4.2524	-25.1902	6
16	4.5988	-28.5820	5
17	4.4418	-27.0915	6
18	4.6459	-27.0684	6
19	4.4850	-24.6530	7
20	—	—	0
N=13	$\bar{X}=4.2867$ SD= .3343	$\bar{X}=-26.1117$ SD=3.1234	$\Sigma =76$

TABLE L
Subject 12 On-hand Raw Data

Trial	Velocity	Angle	Accuracy
6	—	—	0
7	3.9587	-20.6690	6
8	3.6458	-18.4857	3
9	3.5673	-17.5695	2
10	—	—	0
11	3.5849	-24.9752	7
12	3.8505	-23.5825	7
13	3.8951	-22.0536	7
14	3.7707	-24.2864	7
15	3.3959	-21.8420	6
16	3.9628	-23.1480	7
17	3.9758	-19.2164	4
18	4.1803	-23.4595	7
19	3.6844	-20.0333	6
20	3.2554	-23.6907	7
N=13	$\bar{X}=3.7483$ SD= .2586	$\bar{X}=-21.7701$ SD=2.3734	$\Sigma =76$

TABLE M
Subject 1 Off-hand Raw Data

Trial	Velocity	Angle	Accuracy
6	—	—	0
7	—	—	0
8	—	—	0
9	—	—	0
10	3.2316	-24.3590	7
11	—	—	0
12	—	—	0
13	3.0902	-24.4206	7
14	—	—	0
15	3.2216	-16.6110	3
16	3.3909	-20.0286	6
17	2.1917	-16.2900	3
18	—	—	0
19	—	—	0
20	—	—	0
R**	2.9532	-21.8887	*
R	3.3346	-20.6992	*
R	2.7503	-21.8071	*
R	3.3112	-24.9232	*
R	3.0485	-20.0152	*
N=10	$\bar{X}=3.0524$ SD= .3598	$\bar{X}=-21.2253$ SD=3.1985	$\Sigma =26$

NOTE.

** Retrial

* Retrial landed on 6 or 7 point target area

TABLE N
Subject 2 Off-hand Raw Data

Trial	Velocity	Angle	Accuracy
6	3.8842	-27.0000	6
7	3.1939	-19.7447	6
8	3.3836	-16.7244	2
9	3.3756	-16.2849	2
10	2.1268	-17.5510	2
11	—	—	0
12	3.7863	-19.0520	5
13	—	—	0
14	4.3134	-31.8295	4
15	3.5399	-21.2793	6
16	3.5251	-22.5818	7
17	3.7139	-26.2502	6
18	4.0364	-22.6033	7
19	4.0417	-21.6413	7
20	4.9173	-21.4065	6
N=13	$\bar{X}=3.5767$ SD= .5607	$\bar{X}=-21.8422$ SD=4.4265	$\Sigma =66$

TABLE 0
Subject 3 Off-hand Raw Data

Trial	Velocity	Angle	Accuracy
6	3.3241	-21.5127	6
7	—	—	0
8	3.9660	-27.6806	6
9	—	—	0
10	3.3341	-31.9500	3
11	3.4430	-23.2374	7
12	3.3916	-18.2126	4
13	3.7355	-19.0736	4
14	3.4515	-22.2703	7
15	3.4587	-20.3991	5
16	3.1985	-24.7371	7
17	—	—	0
18	3.3061	-38.3955	1
19	3.3373	-23.6443	7
20	—	—	0
R	2.9375	-16.6194	—
R	3.3961	-22.4612	*
R	3.0373	-26.3890	*
N=14	\bar{X} =3.3798 SD= .2548	\bar{X} =-24.0416 SD=5.7356	Σ =57

TABLE P
Subject 4 Off-hand Raw Data

Trial	Velocity	Angle	Accuracy
6	3.9692	-28.9264	5
7	—	—	0
8	4.3737	-26.2086	6
9	3.6048	-23.1034	7
10	3.5872	-16.7452	2
11	3.7650	-22.3172	6
12	—	—	0
13	3.6026	-19.9704	6
14	4.1299	-27.8863	5
15	3.1635	-21.1364	6
16	3.0189	-17.7868	2
17	4.3566	-24.3281	7
18	4.8198	-24.2195	7
19	3.7427	-22.7094	6
20	—	—	0
N=12	$\bar{X}=3.8445$ SD= .6156	$\bar{X}=-22.9448$ SD=3.7175	$\Sigma =65$

TABLE Q
Subject 5 Off-hand Raw Data

Trial	Velocity	Angle	Accuracy
6	4.1349	-22.0362	7
7	—	—	0
8	4.4224	-27.8870	6
9	4.0544	-19.8205	6
10	3.5809	-18.2797	3
11	4.1277	-29.5878	4
12	4.7365	-28.3755	5
13	3.1369	-24.9498	7
14	—	—	0
15	—	—	0
16	3.7259	-20.8024	6
17	3.9372	-22.6069	7
18	5.1473	-22.5058	6
19	4.0446	-22.3215	7
20	4.2137	-18.6501	4
N=12	$\bar{X}=4.1052$ SD= .5213	$\bar{X}=-23.1519$ SD=3.7855	$\Sigma =68$

TABLE R
Subject 6 Off-hand Raw Data

Trial	Velocity	Angle	Accuracy
6	5.2764	-18.9649	5
7	3.3470	-38.1719	1
8	4.2352	-16.2876	2
9	3.6217	-20.3589	6
10	—	—	0
11	3.5684	-17.5764	3
12	3.4397	-21.6368	6
13	3.4535	-17.9562	3
14	2.9515	-16.1053	2
15	—	—	0
16	3.8401	-16.9812	2
17	4.2310	-26.0124	6
18	4.0385	-17.1825	3
19	4.1335	-29.3003	4
20	3.7226	-21.3232	6
R	4.0567	-23.0176	*
R	3.8392	-24.3312	*
R	4.2144	-24.0675	*
R	3.0062	-22.6433	*
N=17	$\bar{X}=3.8221$ SD= .5507	$\bar{X}=-21.8775$ SD=5.6237	$\Sigma =49$

TABLE S
Subject 7 Off-hand Raw Data

Trial	Velocity	Angle	Accuracy
6	3.4571	-28.3690	5
7	3.3545	-32.5182	3
8	2.9404	-21.4440	6
9	—	—	0
10	3.4902	-35.4216	2
11	3.6874	-32.7068	3
12	—	—	0
13	4.3884	-44.1575	1
14	—	—	0
15	3.4891	-20.4099	6
16	3.7554	-25.4234	6
17	2.5169	-25.7908	6
18	3.4118	-21.9911	7
19	3.6447	-33.4248	3
20	3.6888	-20.8551	6
R	4.6786	-44.3415	—
R	3.5045	-24.8967	*
R	3.8135	-20.9638	*
N=15	\bar{X} =3.5881 SD= .5090	\bar{X} =-28.8476 SD=8.0310	Σ =54

TABLE T
Subject 8 Off-hand Raw Data

Trial	Velocity	Angle	Accuracy
6	4.0430	-16.9317	2
7	—	—	0
8	4.2504	-29.5923	4
9	—	—	0
10	4.3050	-29.6445	4
11	4.7082	-32.8687	3
12	4.0183	-29.4759	4
13	3.4830	-17.1893	2
14	4.3609	-25.4032	6
15	4.2344	-37.1169	2
16	3.6127	-27.8597	6
17	3.6492	-30.8409	4
18	4.4399	-23.8429	7
19	4.0888	-26.7089	6
20	4.5437	-26.6508	6
R	4.6065	-31.2233	—
R	4.0237	-23.4275	*
R	3.7214	-25.0271	*
R	4.2763	-17.5972	—
R	3.5421	-22.8035	*
N=18	\bar{X} =4.1060 SD= .3767	\bar{X} =-26.3447 SD=5.5054	Σ =56

TABLE U
Subject 9 Off-hand Raw Data

Trial	Velocity	Angle	Accuracy
6	4.6878	-37.3532	2
7	4.2473	-28.6760	5
8	3.9550	-24.2981	7
9	4.0714	-23.0546	7
10	3.7224	-30.4418	4
11	3.9997	-27.1497	6
12	3.5278	-29.4385	4
13	3.9548	-28.7336	5
14	4.9170	-35.5583	2
15	3.9191	-28.3930	5
16	4.5882	-36.6922	2
17	—	—	0
18	4.2999	-26.8341	6
19	4.4447	-24.4602	7
20	5.0890	-30.9344	4
R	4.4015	-21.3741	*
R	3.5663	-26.2482	*
R	4.2146	-16.9963	—
R	3.8309	-24.7408	*
N=18	$\bar{X}=4.1910$ SD= .4391	$\bar{X}=-27.8543$ SD=5.2526	$\Sigma =66$

TABLE V
Subject 10 Off-hand Raw Data

Trial	Velocity	Angle	Accuracy
6	3.8817	-19.7960	5
7	—	—	0
8	—	—	0
9	—	—	0
10	3.7263	-23.2348	7
11	3.7650	-24.0800	7
12	4.2444	-26.3814	6
13	4.2230	-30.9991	4
14	4.8881	-40.3306	1
15	5.2075	-28.8108	5
16	4.3581	-21.2816	6
17	3.6999	-21.7139	6
18	4.3278	-22.9606	7
19	4.4430	-27.1686	6
20	4.2826	-34.8753	2
R	4.6018	-28.8523	—
R	4.3649	-20.3925	*
R	3.1614	-22.4773	*
N=15	$\bar{X}=4.2540$ SD= .4601	$\bar{X}=-26.2237$ SD=5.7908	$\Sigma =62$

TABLE W
Subject 11 Off-hand Raw Data

Trial	Velocity	Angle	Accuracy
6	—	—	0
7	3.7901	-19.9987	5
8	3.3149	-21.8483	6
9	3.8023	-26.8725	6
10	4.8840	-27.0438	6
11	4.0808	-35.2894	2
12	3.3578	-21.5840	6
13	5.2579	-26.6392	6
14	5.1785	-23.1765	7
15	3.8009	-33.2449	3
16	5.0321	-35.9000	2
17	4.3795	-30.9296	4
18	4.0332	-21.9218	6
19	4.6053	-27.3267	6
20	4.3668	-26.4758	6
N=14	$\bar{X}=4.2774$ SD= .6443	$\bar{X}=-27.0179$ SD=5.1753	$\Sigma =71$

TABLE X
Subject 12 Off-hand Raw Data

Trial	Velocity	Angle	Accuracy
6	3.8711	-31.5043	4
7	—	—	0
8	3.6328	-22.9151	7
9	3.0299	-23.9917	7
10	—	—	0
11	3.4078	-26.2220	6
12	2.4066	-22.6756	7
13	3.7957	-30.0581	4
14	3.2035	-19.1232	5
15	3.3766	-37.1280	2
16	3.4430	-21.2374	6
17	3.6025	-19.2055	5
18	3.2094	-18.8033	3
19	3.2973	-23.3721	7
20	3.3202	-27.1563	6
R	3.4082	-25.6502	*
N=14	$\bar{X}=3.3575$ SD= .3580	$\bar{X}=-24.9316$ SD=5.2298	$\Sigma =69$