The Effects of Weight of Projectile & Arm Segment Lengths on the Accuracy of the Overarm Throw

Michael Hickey
Western Kentucky University

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Michael A.

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THE EFFECTS OF WEIGHT OF PROJECTILE AND ARM SEGMENT LENGTHS ON THE ACCURACY OF THE OVERARM THROW

A Thesis
Presented to
the Faculty of the Department of Physical Education
and Recreation
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In Partial Fulfillment
of the Requirements for the Degree
Master of Arts

by
Michael A. Hickey
May 1972
THE EFFECTS OF WEIGHT OF PROJECTILE AND ARM SEGMENT LENGTHS ON THE ACCURACY OF THE OVERARM THROW

APPROVED June 3, 1922

William B. Koch
Director of Thesis

James Rankin Cooley

Bert E. Oglesby

Edwin C. Hanr

Dean of Graduate College
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Special thanks are extended to the faculty at Jones-Jaggers Laboratory School and T. C. Cherry School, Bowling Green, Kentucky, for allowing the author to do the testing and to the pupils who served as subjects.
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CHAPTER I

INTRODUCTION

One of the interests of kinesiologists has been the application of principles of leverage to human movement as a means of increasing understanding of the characteristics of skills. Movement analysis and the experimental study of the action of body segments serving as levers in the throwing action may promote increased efficiency in teaching and learning of throwing skills in sport and physical education.

In human movement the skeletal system operates as a series of levers obeying general mechanical laws. The nervous and biochemical reactions which allow the muscles to act to move these levers are part of the body's physiological system. Thus the speed and accuracy imparted to a thrown ball is a product of the combined functioning of these two systems. This study was primarily concerned with one aspect of the problem, that is, the effects which the arm length and/or ball weight variations may have upon accuracy.

Statement of the Problem

This study was undertaken for the purpose of investigating whether there was (1) a significant relationship between the length of the segments of the throwing arm and the accuracy of
the overarm throw, and (2) a significant difference in the accuracy of the overarm throw when the weight of the ball was varied.

Need for the Study

In the only other reported studies which have investigated the effects of the use of projectiles of varying weight, the type of throw used was a lobbing action rather than a normal throw. In one of these studies, the subject was required to throw over a horizontal crossbar. In another the subject was required to lob underhand. Obviously, these were non game-like, or artificial, situations.

The motor ability required in any test should be as similar as possible to that required in the more general performance (i.e., sport or game) which is being tested. This point would seem obvious but it is sometimes forgotten. The nearer a test is to the game situation the more meaning it will have for the subject.

Since no other studies using game-like speed of throwing actions have previously been completed, it appeared desirable to carry out such an investigation.

Underlying Hypotheses

The following hypotheses will be investigated:

1. The heavier the ball, the more accurate the throw.

2. The longer the arm segment, the greater the degree of accuracy.
Delimitations of the Study

The following delimitations were placed on the study:

1. Only intermediate grade children (i.e., boys between the ages of eight and eleven years) were considered in selecting subjects. With few exceptions subjects were fourth-graders.

2. The total population of male subjects at two schools was used in this study. No specific selection process relative to their aptitude or ability in throwing skill was utilized.

Definition of Terms

1. The Overarm Throw was defined as a throw in which the ball was released above the level of the shoulder and forward of a straight line connecting the two shoulder joints.

2. The Balls used consisted of three types: the lighter ball was plastic with a hollow interior; the medium weight ball was a similar plastic ball filled with sawdust and shot; and the heavy ball was a regulation 12-inch softball.

Summary

This study was undertaken for the purpose of investigating the possible effect of the variation of the weight of the ball and the length of the arm segment on the throwing accuracy of elementary school boys. Also studied was the combined effect of the interaction of these two factors. Subjects used in the study were the total population of nine and ten year old boys at two elementary schools in Bowling Green, Kentucky.
Although there have been several studies conducted in the area of the throwing accuracy, relatively little research has investigated specifically the effects of variation of the weight of the projectile on accuracy as measured by an objective target.

In a test involving the use of projectiles of different weights Egstrom, Logan, and Wallis found that practice with a light ball was as effective as practice with a heavier ball in developing skill to throw a heavier ball. However, practice with the heavier ball, when transferred to the lighter ball, did not demonstrate a corresponding effect. The authors' explanation of this phenomenon was that the operation of neuromuscular facilitation involving sensory receptor feedback mechanisms in the muscles and joints was sharpened by practice with the lighter ball. That is to say, the use of a lighter projectile made the subject more sensitive to the movement. The type of throw used in the test, however, was rather unusual in that the subject had to employ a lopping action at a horizontal bar (six inches above the subject's standing height) that was placed in front of the

target and was inclined at thirty degrees to the horizontal. Whether the results of this study would transfer to conventional throwing was questionable. Kinser, in a study of basketball free throwing accuracy with the non-preferred hand, found that practice with a light ball developed significantly greater accuracy than practice with a regulation or heavier ball.

Creek, in a test with inexperienced softball players, found that warm-up with a weighted softball has an adverse effect on accuracy. He noted, however, that with repeated testing, accuracy improved showing that the adverse effect of the overload warm-up may have been related to the inexperience in throwing the softball.

Breitinger, in a study of the dependence of athletic achievements to physical characteristics with three thousand high school boys, found almost no connection between the length of the arm and achievement in throwing.

Jable, in a study involving three groups practicing with light (16 oz.), regulation, and heavy (40 oz.) basketballs,

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found that practice with the light and regulation balls improved free-throw shooting accuracy with the regulation ball but practice with the heavier ball did not affect free-throwing performance.

Brophy studied target throwing with college women and found that the reliability increased significantly as the number of trials were increased. Between ten and fifty trials the reliability increased 33.9 percent, showing that more conclusive results were obtained when subjects received a large number of trials.

McCloy and Young maintained that unless at least twenty-five trials are given the coefficients of reliability for this type of test were exceedingly low. However, the New York State Test was validated at twenty throws per subject.

Scott and French maintained that an increase in the number of trials comprising the final score for the test will very often produce an increased reliability coefficient which was not entirely a result of the administration of the test by the same person under similar circumstances. One of the explanations given for this was that up to a point the reliability of a measure increased with the number of trials. The authors also

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believed that if each attempt on an accuracy scoring test was scored on a success or failure basis (as in the New York State Test), the number of trials needed to be greater than if each attempt was scored for relative accuracy, as in a test using a concentric circle target.

In tests involving subjects or players of varying ability the number of trials necessary for a group of advanced players will frequently be fewer than the number required for less experienced players on the same test. This was illustrated by the fact that in a basketball shooting test a reliability coefficient of .676 was established when scoring was based upon actual baskets made in contrast to a figure of .788 when a target-type scoring system was used with the same number of trials.

Clarke noted that though a reliability of .70 to .79 was rather low, it could be expected in accuracy tests of this type and was adequate for group measurement.

Supporting this, Malina stated that the reliability of accuracy tests is highly variable and is specific to the situation in which the test is used and is also specific to the manner in which the reliability is calculated. Furthermore, the age and number of subjects, the number of throws, the type of throw and

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ball, the distance of the throw and the type of target were all factors which affect the reliability of accuracy tests. He found that highest reliability was achieved by using a concentric circle target. From the results obtained in these studies, an objectively judged circular target appeared to be the best to use in this type of investigation.

In relation to the learning aspect of a skill Welford stated that when a person meets a situation or carries out an action he necessarily and inevitably does so in terms of what he brings to it from previous experience. His success will in a large part be determined by how he selects from other situations and actions of his past experience, some of which will be relevant and others not. He also stated that the organization (kinesthetic awareness) of the movement carried over from one trial to another tended to become firmer or more complete with extended usage and that although the organization undergoes considerable modification, the way in which the task is performed the first time it is met may largely determine the manner of its performance subsequently. He also mentioned that total skill achievement was often by no means the same thing as the generally accepted criterion of performance. In many cases this criterion had the status of a score dealing with only one part or aspect of the performance. In many aiming tasks (including this one) the score obtained on the target was only a matter of accuracy and

took no account of time taken, method of aiming, or of other factors.

Tricker and Tricker\textsuperscript{12} stated that a ball, when thrown, was acted upon, not only by the force applied to it by the thrower, but also by its weight. Thus, the ball and the thrower both influenced the accuracy.

Bowne\textsuperscript{13} investigated both overarm and underarm throws and concluded that the position of the acting lever at the moment of release of the ball had considerable predictive power relative to the overhand velocity achieved. However, a similar relationship was not found between structure-length measures and overhand throwing velocity. With underhand throws, results indicated that neither the length of body segments nor the position of the acting lever at the moment of release of the ball was a critical factor in determining the velocity of the throw.

Cearley\textsuperscript{14} found no direct linear relationship between the performance ability for boys and girls aged nine to seventeen and their ability to throw a softball. Thus, apart from boys


\textsuperscript{13}Mary E. Bowne, "The Relationship of Selected Measures of Acting Body Levers to Ball Throwing Velocities," Research Quarterly, 31 (October, 1960), 392-402.

\textsuperscript{14}Jess E. Cearley, "Linearity of Contributions of Ages, Heights and Weights to Prediction of Track and Field Performances," Research Quarterly, 28 (October, 1957), 218-222.
being generally more accurate than girls no conclusive trends were indicated.

Watson,\textsuperscript{15} using college women, conducted a study to determine the degree of relationship that existed between the length of the levers of the arm (as taken by anthropometric measurements at shoulder, elbow, and wrist) and the accuracy and speed of throwing a baseball. Measurements were taken at the head of the humerus, the olecranon process and the distal end of the ulna. Little relationship was found between body measurements and accuracy and distance in throwing a baseball. The correlations between accuracy throwing when compared with physique measurements were lower than those between distance and these factors. However, there was a correlation of .75 between the ability to throw a baseball accurately and the ability to throw it a maximum distance. This could have been caused by the relationship of childhood experience upon the individual and not necessarily between accuracy and distance per se.

Wild\textsuperscript{16} studied the development of throwing in children aged two to twelve years and found several factors influencing the throwing action. A feature common to the overhand throw was a release which started the ball on a nearly horizontal path, regardless of the age of the child or the initial velocity


of the throw. This trait was more pronounced in boys than in girls. Evidence pointed to the possibility that the arm action was largely responsible for the speed imparted to the hand and ball. The time interval from the beginning of the forward swing to the release of the ball became progressively shorter with age. It was during this time that the acceleration resulting in the velocity of the ball at release was built up. Thus with older children the throwing action progressively shortened in terms of both distance moved and time taken. Analysis of the throwing action showed that from the beginning of the forward swing (where there is practically zero velocity) there was definite acceleration to the point of release, after which speed decreased during the follow through. Wild also found that trunk movement did not assist in getting acceleration but that it was a postural and orienting factor for a highly vigorous and rapid arm action.

Wild also found that throwing patterns developed by children were both kinesiological and physiological in nature. These patterns seemed dependent on such neuromuscular faculties as equilibration and orientation. She found the better the development of sensitive proprioceptive mechanisms, the better the development of a basic pattern essential to an intricately timed activity such as throwing. Taking this into account, any subjects regularly playing "little league" baseball might be expected to perform better on the test.
In an experiment with first grade children, Miller\textsuperscript{17} found that instruction in the overhand throw for accuracy showed no statistically significant difference between the mean gains of the experimental and control groups for both boys and girls, although the experimental group had consistently higher mean gains. He concluded that there was no more improvement in the investigation than would be expected to occur by practice without instruction.

Hicks\textsuperscript{18} came to a similar conclusion in an experiment with children from two to eight years of age who were given eight weeks training in throwing, even though his study involved a moving target rather than a stationary one.

In a similar study with children from three to seven years of age instructed in throwing for distance, Dusenberry\textsuperscript{19} found that training produced a significant increase in throwing ability.

\textsuperscript{17} James L. Miller, "Effect of Instruction on Development of Throwing for Accuracy of First Grade Children," Research Quarterly, 28 (May, 1957), 132-137.

\textsuperscript{18} J. Allen Hicks, "The Acquisition of Motor Skill In Young Children," Child Development, 1 (June, 1930), 296.

Gesell,²⁰ Gutteridge,²¹ and Jenkins²² compared the initial throwing ability of children and found that this skill increased with each age level from two to twelve years, with boys showing a definite superiority over girls at all age levels.

Moffett,²³ in a study of accuracy in target throwing, found that as the throwing distance was increased from fifteen to thirty feet, accuracy of direction to the left of the center of the target decreased. However, from thirty feet, increased distance did not add to inaccuracy in the same direction. He also found that there were no significant decreases or increases in accuracy to the right, above, or below the center of the target when the distance from the center of the target was increased by fifteen foot intervals from fifteen feet to seventy-five feet.

Summary

From the literature reviewed it would be expected that arm movements rather than the action of the whole body would determine the speed and accuracy of the throw, and that older

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²¹Mary V. Gutteridge, "A Study of Motor Achievement of Young Children," Archives of Psychology, 244 (1939), 178.

²²Lulu M. Jenkins, "A Comparative Study of Motor Achievements of Children of Five, Six, and Seven Years of Age," Teachers College Contributions to Education, 414 (1930), 54.

subjects would show better performance than younger ones. It would also appear that those subjects with previous experience of throwing in a sports or a game situation would score better on the test.
CHAPTER III

PROCEDURES AND EXPERIMENTAL DESIGN

All subjects were tested at their respective schools. It was therefore necessary to construct portable testing equipment. This procedure allowed the testing to be conducted in different situations but under controlled conditions. It further insured that all subjects were tested with the same equipment thereby eliminating the possible influence of variable factors such as different groups of subjects being tested with a different target.

Selection of Subjects

Only boys were used for the test and all were taken from the Jones-Jaggers Laboratory School and the T. C. Cherry School, both in Bowling Green, Kentucky. They comprised the entire sample of boys at the fourth grade level, with the condition that any below the age of nine years or above eleven years as of January 31, 1972, were excluded.

Description of Test

The test used was one for accuracy in throwing, which was one of a battery of test items comprising the New York State Physical Fitness Test. When performing this test item as part
of the total battery the subject was required to throw a softball twenty times at the target. This particular test was chosen because it had been validated, provided a motivating challenge to the subject, and could be scored objectively.

Description of Testing Equipment

The target consisted of a piece of heavy white canvas, measuring four feet by four feet, on which was painted a circle with an outside diameter of two feet. The circumference of the circle had a width of one inch, making the inside diameter twenty-two inches. At the top and bottom of the target the canvas was doubled over and sewn to form a pocket. Through the pockets two one-inch square lengths of wood were passed. These served to keep the face of the target taut. Staples driven into each end of the top length of dowelling enabled a length of cord to be fed through the opening. The target was then suspended from a nail on the wall with the target center four feet from the floor surface.

The throwing line was marked on the floor thirty feet back from the center of the target with one-inch wide masking tape. The balls used were:

1. a lighter plastic ball with a hollow interior (the lighter ball--2½ oz.)

2. a similar plastic ball filled with sawdust and lead shot (the medium weight ball--5 oz.)
3. A regulation twelve-inch softball (the heavier ball -- 7 1/2 oz.)

Thus, the weights of the balls were in the ratio 1:2:3.

Description of Testing Procedure

Subjects were required to stand behind the throwing line and by using an overarm throw, they attempted to hit the target as many times as possible in six series of ten throws each. Thus, each subject had sixty throws with the condition that there were twenty throws per subject with each of three different weighted balls. That is, each group of ten throws used the same weight of ball, but the series of six groups were in a random order of the three different weights. To randomize the different weights of ball used in the six groups of throws, subjects were required to take six discs numbered from one to six from an opaque plastic container. Discs one and two represented the lighter ball, three and four the medium ball, and five and six the heavier ball. Therefore, the order in which the discs were taken determined the order in which the groups of different weighted balls were thrown. The throws were grouped into tens to facilitate testing and mathematical computation.

Scoring of Test

One point was counted for each time the ball hit the target and balls hitting the circumference line were counted as "good."

Throws were judged by the observation of the investigator.
Experimental Controls Employed

The test was conducted in school gymnasiums which had either wooden or tile floors. Lighting was the same as would be expected for normal physical education class activities. Subjects were dressed in shorts and vest for the testing session to insure that their throwing action was not impeded by any restrictive clothing. Subjects threw at their own pace and were not required to complete any given number of throws in a specific time limit. The only person observing the subjects throwing was the investigator.

Instruction to Subjects

Subjects were instructed to be as accurate as possible while maintaining the throwing speed that they would normally use while playing a game of softball. They were not permitted to lob the ball at the target or to slow down the throwing action to enable them to concentrate solely on accuracy. Specific instructions given to each candidate are presented in Appendix A.

Anthropometric Measurements

To determine the length of the forearm segment, measurements were taken from the tip of the acromion process to the distal end of the styloid process of the ulna. These points were palpated and "spotted" with a fine-tip felt pen before the actual measurements were taken with a steel tape.
Statistical Methodology

The statistical design employed was a $3 \times 3$ factorial design with repeated measures over the three arm lengths. Means were computed as measures of central tendency, while standard deviations and standard errors of the mean were used as indices of dispersion.

The critical level of probability was determined prior to the investigation and set at the .05 level. Critical value tables provided by Steel and Torrie$^1$ were consulted prior to the acceptance or rejection of the null hypotheses.

The data were analyzed by an IBM-360 computer and computer time was furnished by the Computer Science Center of Western Kentucky University.

Summary

The test used in this study was the accuracy item of the New York State Physical Fitness Test. Fifty-five boys between nine and eleven years of age who were students at two different elementary schools were selected as subjects for the study.

The target was a twenty-four inch diameter circle with its center four feet above floor level. Subjects threw three different weighted balls the same size as a regulation softball from a distance of thirty feet. The balls used were of three weights: $2\frac{1}{4}$, 5, and $7\frac{1}{2}$ ounces. They were thrown in random order

in groups of ten. Throws were scored objectively by the investigator with one point scored for each "good" throw. Subjects threw at their own pace and were observed only by the investigator.

To determine the length of the arm segment anthropometric measurements were taken from the tip of the acromion process to the distal end of the styloid process of the ulna.

Sets of cards were key-punched at the Computer Center, Western Kentucky University, and the data were analyzed by an IBM-360 computer. A 3 x 3 factorial design of analysis of variance was computed to find possible significant differences due to the individual treatments and their interaction.
CHAPTER IV

ANALYSIS AND INTERPRETATION OF DATA

This chapter contains the results of the analysis of the data that were collected during the conduct of the experiment.

Collection of Data

Anthropometric measurements were taken with a steel tape to determine arm lengths. Short arm lengths were defined as those measuring up to and including 23.0 inches, medium arm lengths as those measuring between 23.1 inches and 24.0 inches inclusively, and long arm lengths as those measuring 24.1 inches and longer. These three lengths were selected in order to allow three approximately equal sized groups of scores to be established.

Ball weights were defined as light, medium and heavy. Their weights were 2½ ounces, 5 ounces and 7½ ounces, respectively.

Presentation of Data

Descriptive statistics for each of the nine cells in the experiment are presented in Table 1. Mean scores, standard deviations and standard errors of the mean are included. The means ranged from 5.50 to 7.77 and standard deviations ranged from 2.62 to 3.57.
TABLE 1
DESCRIPTIVE STATISTICS BY CELL INVOLVING
ARM LENGTH AND BALL WEIGHT

<table>
<thead>
<tr>
<th>Arm Length*</th>
<th>Ball Weight (oz.)</th>
<th>n</th>
<th>$\bar{X}$</th>
<th>s</th>
<th>$\bar{s}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short</td>
<td>$2\frac{1}{2}$ (Light)</td>
<td>12</td>
<td>6.33</td>
<td>2.62</td>
<td>0.76</td>
</tr>
<tr>
<td>Short</td>
<td>$5$ (Medium)</td>
<td>12</td>
<td>5.58</td>
<td>2.69</td>
<td>0.78</td>
</tr>
<tr>
<td>Short</td>
<td>$7\frac{1}{2}$ (Heavy)</td>
<td>12</td>
<td>6.17</td>
<td>3.16</td>
<td>0.91</td>
</tr>
<tr>
<td>Medium</td>
<td>$2\frac{1}{2}$ (Light)</td>
<td>21</td>
<td>5.95</td>
<td>3.23</td>
<td>0.70</td>
</tr>
<tr>
<td>Medium</td>
<td>$5$ (Medium)</td>
<td>21</td>
<td>6.00</td>
<td>3.37</td>
<td>0.73</td>
</tr>
<tr>
<td>Medium</td>
<td>$7\frac{1}{2}$ (Heavy)</td>
<td>21</td>
<td>6.10</td>
<td>3.01</td>
<td>0.66</td>
</tr>
<tr>
<td>Long</td>
<td>$2\frac{1}{2}$ (Light)</td>
<td>22</td>
<td>5.50</td>
<td>2.74</td>
<td>0.58</td>
</tr>
<tr>
<td>Long</td>
<td>$5$ (Medium)</td>
<td>22</td>
<td>6.77</td>
<td>2.98</td>
<td>0.64</td>
</tr>
<tr>
<td>Long</td>
<td>$7\frac{1}{2}$ (Heavy)</td>
<td>22</td>
<td>7.77</td>
<td>3.57</td>
<td>0.76</td>
</tr>
</tbody>
</table>

*Short--up to and including 23.0 inches
Medium--23.1 inches to 24.0 inches inclusive
Long--24.1 inches and longer

Table 2 includes descriptive statistics for ball weight (Treatment A) averaged across the three levels of arm length (Treatment B). Means ranged from 5.855 to 6.782 and standard deviations ranged from 2.959 to 3.403.

TABLE 2
PRESENTATION OF TREATMENT A MEANS (BALL WEIGHT)
AVERAGED ACROSS LEVELS OF B (ARM LENGTH)

<table>
<thead>
<tr>
<th>Ball Weight (oz.)</th>
<th>n</th>
<th>$\bar{X}$</th>
<th>s</th>
<th>$\bar{s}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$2\frac{1}{2}$ (Light)</td>
<td>55</td>
<td>5.855</td>
<td>2.959</td>
<td>.40</td>
</tr>
<tr>
<td>$5$ (Medium)</td>
<td>55</td>
<td>6.218</td>
<td>3.143</td>
<td>.42</td>
</tr>
<tr>
<td>$7\frac{1}{2}$ (Heavy)</td>
<td>55</td>
<td>6.782</td>
<td>3.403</td>
<td>.46</td>
</tr>
</tbody>
</table>
Table 3 includes descriptive statistics for the arm lengths (Treatment B) averaged across the three levels of ball weight (Treatment A). Means ranged from 2.893 to 3.278.

**TABLE 3**

**PRESENTATION OF TREATMENT B MEANS (ARM LENGTHS) AVERAGED ACROSS LEVELS OF A (BALL WEIGHTS)**

<table>
<thead>
<tr>
<th>Arm Length*</th>
<th>n</th>
<th>$\bar{X}$</th>
<th>S</th>
<th>$S\bar{X}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short</td>
<td>12</td>
<td>6.028</td>
<td>2.893</td>
<td>.84</td>
</tr>
<tr>
<td>Medium</td>
<td>21</td>
<td>6.016</td>
<td>3.230</td>
<td>.71</td>
</tr>
<tr>
<td>Long</td>
<td>22</td>
<td>6.682</td>
<td>3.278</td>
<td>.70</td>
</tr>
</tbody>
</table>

*Short--up to and including 23.0 inches
Medium--23.1 inches to 24.0 inches inclusive
Long--24.1 inches and longer

An analysis of variance employing a 3 x 3 factorial design with repeated measures over the three arm lengths was computed and the results are presented in Table 4. For Treatment A an F-ratio of 3.15 was required for significance and for the AB interaction, an F-ratio of 2.44 was required for significance. The table indicates that Treatment B (arm length) yielded a non-significant F-ratio of .37 ($p > .05$). Treatment A (ball weight) yielded a significant F-ratio of 3.47 ($p < .05$).
### TABLE 4

**SUMMARY OF ANALYSIS OF VARIANCE OF ARM LENGTHS, BALL WEIGHTS, AND THEIR INTERACTION**

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Among Subjects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>17.34</td>
<td>8.67</td>
<td>0.37</td>
</tr>
<tr>
<td>Subject(s)</td>
<td>52</td>
<td>1217.61</td>
<td>23.42</td>
<td></td>
</tr>
<tr>
<td><strong>Within Subjects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>2</td>
<td>24.01</td>
<td>12.01</td>
<td>3.47*</td>
</tr>
<tr>
<td>AB</td>
<td>4</td>
<td>37.02</td>
<td>9.25</td>
<td>2.68</td>
</tr>
<tr>
<td>AS</td>
<td>104</td>
<td>359.64</td>
<td>3.48</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>164</td>
<td>1655.61</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant at .05 level.

With two degrees of freedom an F-ratio of 3.15 was needed for significance. The table indicated that Treatment B (arm length) had no significant effect on the accuracy of the subjects and that Treatment A (ball weight) did have a significant effect.

Table 5 presents Tukey's W test of the three levels of ball weights averaged across arm lengths. A critical ratio for significance at the .05 level was .81. The table values indicate that the heavy ball performances were significantly different
from the light ball performance. The differences between the light and medium, and medium and heavy weights were not significant.

**TABLE 5**

**PRESENTATION OF TUKEY’S W TEST OF THREE LEVELS OF BALL WEIGHS AVERAGED ACROSS ARM LENGTHS**

<table>
<thead>
<tr>
<th>Ball Weight (oz.)</th>
<th>n</th>
<th>$\bar{X}$</th>
<th>Light</th>
<th>Medium</th>
<th>Heavy</th>
</tr>
</thead>
<tbody>
<tr>
<td>2$\frac{1}{2}$ (Light)</td>
<td>55</td>
<td>5.855</td>
<td>-----</td>
<td>.362</td>
<td>.927*</td>
</tr>
<tr>
<td>5 (Medium)</td>
<td>55</td>
<td>6.218</td>
<td>-----</td>
<td></td>
<td>.574</td>
</tr>
<tr>
<td>7$\frac{1}{2}$ (Heavy)</td>
<td>55</td>
<td>6.782</td>
<td>-----</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant at .05 level.

An analysis of the AB interaction yielded a significant F-ratio of 2.58 ($p<.05$) which indicated a lack of independence of the two factors. Further examination of the graphic illustration of the levels of Treatment B across the levels of Treatment A are shown in Figure 1 and indicate that the interaction effect was due to difference of direction because of the change of ball weight from light to medium for all three arm lengths. Secondly, a small difference of direction existed between short and medium arm lengths and also a difference in magnitude for long arm length when a heavy ball was utilized.

Figure 2 presents a graphic illustration of the different ball weights across the levels of arm lengths. The difference in direction interaction was due to the light ball results across the three arm lengths. However, a difference in magnitude
Fig. 1.--Response Scale of the Levels of Treatment B Across the Levels of Treatment A.
Fig. 2.--Response Scale of the Levels of Treatment A Across the Levels of Treatment B.
interaction due to the other two ball weights across the levels of B was also evident.

Discussion of Results

The results of this study indicated that within the limits of the experiment there were no significant differences in the accuracy of the three groups of varying arm length.

Although her study was more concerned with velocity rather than accuracy of throwing, Bowne\(^1\) found no relationship between structure-length measures and overhand throwing ability. Similarly, the results here agree with the conclusions reached by Watson\(^2\) who found little relationship between the length of the levers of the arm and the accuracy and speed of throwing a baseball. The results were also in agreement with the findings of Breitinger\(^3\) who found almost no relationship between the length of the arm and achievement in throwing in a test with high school boys.

In this study, with regard to ball weight, the results indicated that while there were no significant differences between the light and medium, and medium and heavy weights, there was a significant difference between the light ball and the heavy ball.

This would seem to be in disagreement with the findings of Jable\(^4\) who found in a study of basketball shooting that practice

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\(^1\)Bowne, op. cit., 392-402.

\(^2\)Watson, op. cit., 131-141.

\(^3\)Breitinger, op. cit., 85-91.

\(^4\)Jable, op. cit.
with a heavy ball had no effect on free throw shooting accuracy, whereas practice with lighter and regulation balls did. However, Jable's study was concerned with the effects of practice rather than accuracy per se and the heaviest ball used was above regulation weight while in this study the heaviest ball was regulation weight.

Summary

Fifty-five subjects were tested on the accuracy item of the New York State Physical Fitness Test. Their accuracy in relation to factors of varying arm length and varying weight of the ball thrown was statistically analyzed. The F-ratio of 0.37, computed in the analysis of variance design, showed that the factor of varying arm length did not have a significant effect on throwing accuracy. The F-ratio of 3.47, computed in the analysis of variance design, showed that the factor of varying ball weight had a significant effect on accuracy. The F-ratio of 2.68 computed showed that the interaction of the two factors had a significant effect on accuracy.
Summary

The purpose of this study was to investigate the effects of the length of the throwing arm and the effects of the variation of the weight of the ball on the accuracy of the overarm throw. The subjects consisted of the entire sample of boys at the fourth grade level from the Jones-Jaggers Laboratory School and the T. C. Cherry School, both in Bowling Green, Kentucky. There were a total of fifty-five subjects, all between the ages of nine and eleven years.

The test used was the accuracy throwing item which appeared in the New York State Physical Fitness Test Battery. Sixty throws, in groups of ten, were administered to each subject.

Before being tested each subject was read the same set of instructions and questions were answered by the investigator. Itemized individual performances and the total scores were recorded on personal data sheets along with such information as date of birth, height, weight, and the preferred throwing arm. The subjects' throws were scored on the basis of one point for each successful throw.

Sets of computer cards were key-punched at the Computer Center, Western Kentucky University, and an analysis of variance
employing a 3 x 3 factorial design with repeated measures over
the three arm lengths was computed. The F-ratios obtained were
then tested for the possible significant effects of the length of
the throwing arm, the variation of the weight of the ball, and
the interaction between those two variables.

Conclusions

Within the limitations of this study the following
conclusions were drawn from the data gathered in this investigation:

1. The length of the throwing arm did not have a
   significant effect on the accuracy of the subjects.

2. There was a significant relationship between the
   weight of the ball and the accuracy of the subjects. Although
   subjects became progressively more accurate as the ball weight
   was increased, the significant difference was between the light
   and the heavy ball but not between the contiguous weights of the
   ball.

3. The interaction between arm length and ball weight
   was significant at the .05 level.

Recommendations

1. Further testing with three weights of ball as in
   this study, but with the weight of the ball distributed in such
   a manner as to have the regulation ball weight fall somewhere
   in between the lightest and heaviest ball.
2. Further testing with subjects in the same age range to verify the conclusions reached in this study, perhaps with different types of balls and with girls as well as boys.

3. Further testing with subjects who had been selected for the characteristics of extra short and extra long arm lengths. In this study the arm lengths were spread over a range of only three or four inches. To obtain this effect, a wider range of ages would probably have to be sampled.
APPENDIX A

STANDARDIZED INSTRUCTIONS

The following instructions were read to each subject just before taking the test:

1. This is a test to see how good you are at throwing.

2. These three balls are the same size but their weights are different.

3. You will throw them at that circle on the target. Each time you hit inside the circle you will receive one point. Any ball which hits the circle on the line will also count as a good throw.

4. You will throw from behind this line on the floor which is thirty feet from the target. You can move your feet but you must not step over the line as you throw.

5. I want you to use an overarm throwing action. Throw the ball so that it is released above the level of your shoulders and in front of them (Demonstrate).

6. Do not slow down the throwing action to try and be more accurate. Don't use a lobbing action--throw the ball at the same pace as you would while playing a game of softball.

7. There is no time limit. It is not a race, so just throw the balls at your own pace.

8. You will have sixty throws in groups of ten. To find out the order you will throw them in, you will take these numbered discs one at a time from this container. Numbers one and two represent the light ball, three and four the medium ball, and five and six the heavy ball.

9. You may have a few practice throws if you wish.

10. Have you any questions? (Answer any questions subjects may have.)
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Hieronymus,

Steve

1977
COMPARISON OF IRON SUPPLEMENTS FOR THE
PREVENTION OF ANEMIA IN YOUNG PIGS

A thesis
Presented to
the Faculty of the Department of Agriculture
Western Kentucky University
Bowling Green, Kentucky

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by
Steve Hieronymus
May, 1977
COMPARISON OF IRON SUPPLEMENTS FOR THE PREVENTION OF ANEMIA IN YOUNG PIGS

Director of Thesis

Approved: April 29, 1977

Dean of the Graduate College

Approved: May 6, 1977
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</tr>
<tr>
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<td>21</td>
</tr>
<tr>
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<td>1. Schematic diagram of iron absorption and storage in the body</td>
<td>8</td>
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Comparation of iron supplements for the prevention of anemia in young pigs

Steve Hieronymus

April 1977

Directed by: Dr. Gordon Jones, Dr. Leonard Brown and Mr. Billy Adams

Department of Agriculture Western Kentucky University

Crete Koate, a product originally intended to be utilized for absorbing excess moisture and reducing knee abrasions of baby pigs raised in confinement, was tested as a hematinic for young pigs. Four treatments were studied: (1) T-NI, pigs receiving no iron; (2) T-IS, pigs receiving a 2 ml intramuscular injection of iron-dextran at 2 days of age; (3) T-CK, pigs raised in pens treated daily with Crete Koate; (4) T-ISCK, pigs receiving an intramuscular injection of iron-dextran on day 2 whose pens received daily treatments of Crete Koate. Hemoglobin levels were used as an indicator of iron status in the body and weights were used as a measure of production.

Blood samples taken at 14 days of age revealed differences (P<.01) in hemoglobin levels among treatments. Those treatments supplying iron, T-IS, T-CK, and T-ISCK, maintained higher (P>.01) hemoglobin levels than the control, T-NI. Weights did not significantly differ among treatment groups at either 14 or 28 days (P>.10).

There was no observable difference in knee scuffing among treatments. However, those pens receiving Crete Koate appeared to stay drier and cleaner.

Results of this study suggest that Crete Koate may