



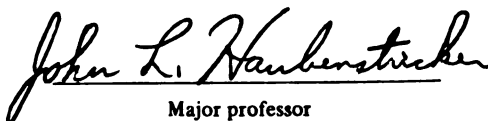
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THE RELATIONSHIP BETWEEN QUALITATIVE AND
QUANTITATIVE EVALUATION OF THROWING
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RANDALL LEE BAKER

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THE RELATIONSHIP BETWEEN QUALITATIVE AND
QUANTITATIVE EVALUATION OF THROWING

by

Randall Lee Baker

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
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ABSTRACT

THE RELATIONSHIP BETWEEN QUALITATIVE AND QUANTITATIVE EVALUATION OF THROWING

By

Randall Lee Baker

This study examined the effect of gender, grade, and throwing pattern on the distance children threw a ball. Children (n=303) in grades K-5 were assessed on throwing pattern, throwing distance, grip strength, push-ups, height, and weight. Results showed that boys threw a ball farther than girls in each grade; older children (grades 3-5) threw farther than younger children (grades K-2); and, girls with a mature pattern threw farther than girls with less mature patterns. Throwing pattern in boys could not be analyzed because of the high percentage (94%) who threw with a mature pattern. Regression analyses revealed that grip strength, height, and push-ups also influenced the distance throws of children. The results of this study, plus the importance of factors not studied such as practice time and motivation, led to the conclusion that the throwing performance of children is dependent on more than gender, grade, and throwing pattern.

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This thesis is dedicated to my wife, Dianna. Without her help and encouragement, this thesis never would have been written.

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CHAPTER 1

INTRODUCTION

The overhand throw is an important skill in many games and sports in American culture. The ability to throw with force and with accuracy is critical to success in sports such as baseball, football, and basketball, as well as in many of the games and activities in which children participate. Because of its importance in games and sports, physical educators, coaches, and researchers have sought various means by which to assess the throwing ability of individuals.

The research literature contains numerous investigations that focus on the evaluation of throwing ability. These extensive investigations have resulted in a variety of approaches to evaluate throwing ability. The approaches may be grouped into two categories, those which focus on the outcome of throwing and those that examine the process of throwing.

Achievement scores have long been used to determine throwing ability. The most common score is the distance a ball can be thrown in the air (AAHPER, 1965; Espenchade, 1960; Hanson, 1965; Hartman, 1943; Jenkins, 1930; Keogh, 1965; Morris, Williams, Atwater, & Wilmore, 1982). Measuring the accuracy with which a ball is thrown is another method used to evaluate throwing (Fredrick, 1977; Hicks, 1930; Keogh, 1965; Miller, 1957). A third approach is to measure the velocity of the ball as it leaves the hand of the thrower (Glassow, Halverson, & Rarick, 1965; Glassow & Kruse, 1960; Halverson, Robertson, & Langendorfer, 1982; Halverson, Robertson, Safrit, & Roberts, 1977; Robertson, Halverson, Langendorfer, & Williams, 1979).

The motion which produces the force to propel the ball also has been examined. For example, anatomical, biomechanical, or kinesiological variables have been used to examine parts of the throw such as stride length (Schutzler, 1980), increased range of motion (Luedke, 1980), rotation of various joints involved in throwing (Lyon, 1961; Ekern, 1970; Sanders, 1977; Vaughn, 1982), speed and acceleration/deceleration of body parts involved in the throw (Deutsch, 1969), and the timing of the sequence of the body parts (Atwater, 1970).

Other investigators, especially those at Michigan State University and the University of Wisconsin at Madison, have proposed developmental sequences for fundamental motor skills including throwing. These sequences organize the anatomical and biomechanical information into stages or steps through which performers progress as they develop a better throw (Robertson, 1982; Seefeldt & Haubenstricker, 1982).

Complicating the evaluation of throwing ability are several factors which influence throwing performance. Factors which have been shown to influence throwing performance are strength, body size, form and instruction.

Strength has been shown to be a major factor in the performance of many motor skills but rarely has been a good predictor for success in a skill by itself (Johnson & Nelson, 1979). There is a wide range among the correlation coefficients computed between strength and throwing distance. Correlation coefficients between strength and throwing distance ranged between .31 and .42 for Sullivan (1970) and between .41 and .71 for Espenschade (1940). Significant relationships were found between throwing velocity or distance and specific strength measures such as shoulder strength (Brumfield, 1969), grip strength (Richardson,

1976), and strength of wrist extension and elbow extension (Pegdagana, Elsner, Roberts, Land, & Farewell, 1982). Several studies (Bagonzi, 1979; Rowlands, 1962; Sullivan, 1970) have shown that strength development has increased a person's ball throwing velocity. On the other hand, several studies (Barrow, 1960; Hardison, 1971; Staub, 1966; Williams, 1985) report that strength building programs have not increased a person's throwing distance or velocity.

In examining the relationship between body size variables and throwing ability, Eoff (1985) found height, weight, arm length, and subcutaneous fat to be predictive of throwing ability in young boys, and arm length to be predictive of throwing ability in young girls. Mahmoud (1979) reported significant relationships between the distance a ball was thrown and height, hand, and forearm length. However, no significant relationships between height or weight and throwing performance were found by other researchers (Espenchade, 1940; Fredrick, 1977; Johnson, 1960; Seils, 1951). Other studies (Bowne, 1960; Richardson, 1976; Sanders, 1977) also concluded that there was not a significant relationship between arm length and throwing performance in high school or college students.

Biomechanical factors found to be associated with a better throw are an increase in the range of trunk rotation (Bowne, 1960; Ekern, 1970; Singer, 1961); a decrease in the medial rotation of the arm (Bowne, 1960; Ekern, 1970); better ratings of form for trunk and foot action (Nelson, Thomas, Nelson, & Abraham, 1986); rapid sequential acceleration and deceleration of trunk and arm segments prior to release (Atwater, 1970; Deutsch, 1969); an increase in stride length (Deutsch, 1969; Ekern, 1970; Schutzler, 1980); a greater forward flexion at the

hip joint at the point of release (Ekern, 1970; Lyon, 1961); and, a greater range of movement in contributing joints (Singer, 1961).

Instruction has been found to improve throwing performance in some cases (Dusenberry, 1952; Hoffman, 1969; Luedke, 1980; Mahmoud, 1979; Miller, 1978; Potter, 1963) while in other cases it did not significantly increase throwing distance or velocity (Deatrick, 1977; Dohrman, 1964; Glassow et al., 1965; Halverson et al., 1977; Nichols, 1971; Robertson et al., 1979).

Need for the Study

Although the product and process of throwing have been studied separately, there has not been an attempt to compare the quality of the throwing motion as determined by a developmental sequence with the resultant quantitative measure of the distance a ball is thrown. The advancement from a lower developmental stage of throwing to a more mature stage has not been verified to produce a concurrent improvement in the distance a ball is thrown.

The primary reason for becoming aware of a developmental sequence for a fundamental skill like throwing is to help the learner become more proficient in the skill. A good evaluation describes the present skill level of the learner, whereas the developmental sequence suggests a systematic progression to help the student obtain an optimal skill level. Evidence of an effective developmental sequence is that subjects at a more mature stage generally achieve a better performance score than subjects at a less mature stage. It is important that a more mature throwing pattern has an impact on performance, otherwise there would be no need for teachers to instruct students to achieve a mature throwing pattern. And there would be no need for correction of a thrower's

movement pattern. Emphasis then would be placed on throwing the ball as far as possible regardless of the pattern, or upon other factors such as increasing body strength. One way to evaluate a developmental sequence is to determine if each successive stage reflects an increase in quantitative performance when comparing children of similar age and/or strength. Research is needed to determine if such a relationship exists between the quality of the throwing motion and the outcome of the throw.

Purpose of the Study

The purpose of this study was to establish the validity of a developmental sequence of throwing as a measure of throwing performance. This study examined the relationship between the quantitative aspects of throwing using the distance a ball was thrown and the qualitative aspects of the movement content using the developmental sequence for throwing proposed by researchers at Michigan State University. To accomplish this purpose, the study required: (a) information on the stage of throwing of males and females in kindergarten through the fifth grade; (b) measurements of the children's strength; (c) determination of the relationship between the developmental stage of throwing and throwing distance; and, (d) determination of the relationship between strength and throwing distance.

Limitations

This study was limited to the use of an available sample of students in kindergarten through fifth grade in a school with particular characteristics. Thus the conclusions can pertain only to samples with similar characteristics. This study also was limited to the overhand throw and the results should not be generalized to any other motor

skill. This study was limited by the fact that the motivation of the students could not be completely controlled even though an attempt was made to encourage the subjects to do their best. Because of the use of intact classes, the range of throwing stages, class size, and male to female ratio were not controlled. The residual fallout effects caused by the students who chose not to participate also might have influenced the results of the study. A final limitation was that the developmental sequence of throwing used to evaluate the quality of throwing has not been validated with longitudinal data.

Hypotheses

This investigation tested three hypotheses. The first two hypotheses have been shown to be true in previous studies and were tested to see if they were true for this study also.

- 1) For each grade level, boys will throw a ball farther than will girls.
- 2) Members of the same gender in a higher grade will throw a ball farther than those in a lower grade.

The primary hypothesis of this investigation is that:

- 3) Children of the same grade and gender who have a more mature pattern of throwing as determined by the Michigan State University developmental sequence will throw a ball farther than children who exhibit a less mature stage of throwing.

Factors other than form can affect the distance a ball is thrown. While the primary hypothesis proposed that stage of throwing is an important variable in determining throwing distance, the strength, weight, and height of a child also may influence throwing performance.

Children who are taller, heavier, and/or who possess greater strength theoretically should be able to throw a ball farther than children who are shorter, lighter, and/or weaker. The relationship of weight, strength, and height to throwing form has not been established, therefore their potential impact on throwing performance will need to be controlled.

CHAPTER 2

SURVEY OF RELATED LITERATURE

This study examined the relationship between two methods of evaluating the throwing ability of individuals. The first means was a distance throw. This is the oldest and most common method used to evaluate throwing. A second means of evaluating throwing was to study the motor pattern individuals use to throw a ball. Instead of being concerned with an achievement score produced by the throw, this evaluation is concerned with the movements involved in making the throw.

Research on throwing ability is complicated by the different methods used to evaluate throwing ability. The assessment of a motor skill can be expressed in several ways, but most often it is indicated by an achievement score (Wickstrom, 1983). The most common measure of throwing ability is the distance a person can throw a ball. However, throwing ability also can be measured by initial ball velocity, accuracy or form. Glassow (cited in Halverson et al., 1977) pointed out that the distance a ball is thrown is a function of initial velocity and the angle of projection. She advocated recording both components of distance to identify more precisely the contribution of each. Film analysis or a velocimeter can be used to determine initial velocity (Glassow et al., 1965; Halverson et al., 1982; Halverson et al., 1977; Nichols, 1971; and Robertson et al., 1979). Another achievement score that is used to evaluate throwing is accuracy (Fredrick, 1977; Keogh, 1965; and Miller, 1957). A fourth way to measure throwing ability is to study the movement involved in producing the result. To some

researchers, the distance a ball is thrown is not as important as the throwing motion used to propel the ball (Deach, 1950; Gutteridge, 1939; Mahmoud, 1979; Robertson & Halverson, 1984; Ryan, 1977; Seefeldt & Haubenstricker, 1976d; and Wild, 1938). Numerous biomechanical and kinesiological factors also have been proposed to affect the throwing motion.

This literature review will examine the different methods of evaluating throwing with the exception of the use of evaluation by biomechanical and kinesiological means. Most of the studies which examine throwing by these means have used mature subjects who are participating in a baseball program either at the high school, college or professional level. They have examined parts of the mature throw such as stride length, the rotation of various joints, speed and acceleration/deceleration of body parts, and the timing of the sequence of body part movements. Review of all the investigations regarding biomechanical and kinesiological implications of the throwing motion does not fit into the scope of this study. Readers interested in the biomechanical aspects of throwing are directed to Hay (1985), Gowitzke and Milner (1988), and Kregghbaum and Barthels (1985). A listing of studies involving the biomechanical analysis of throwing is provided by Wickstrom (1983).

Research on throwing ability must also account for other factors that may affect throwing. Such factors include age, gender, body size, and strength. They stimulate questions such as: Is there a difference in the throwing ability of boys and girls? Can a stronger, taller subject generate more power and therefore throw the ball farther than a smaller, weaker subject even if the smaller subject has better form? Is

age a factor in throwing? Are there other measures which give some subjects an advantage over others when throwing a ball for distance?

The review of literature will focus on methods of evaluating throwing: (a) accuracy; (b) distance; (c) initial velocity; and, (d) form. Following these four methods of evaluating throwing, factors affecting throwing ability will be examined. These factors include: (a) gender; (b) strength; and, (c) body size.

Methods of Evaluating Throwing

Various approaches to evaluating throwing behavior have been reported in the literature. The most common of these include the assessment of accuracy, distance, initial velocity, and form.

Accuracy

Accuracy is an important component in a mature throw, especially when throwing is used in a game or play situation. Accuracy is a major way of evaluating throwing (Frederick, 1977; Hicks, 1930; Keogh, 1965; Miller, 1957; Van Slooten, 1973; and Wester, 1939). While it is difficult to summarize the results of the accuracy test studies because of the different size balls (therefore different methods of throwing) and the variety of tests used, two general trends have been identified. First, boys were found to be significantly more accurate in throwing than girls of similar age. Second, both girls and boys showed an improvement in accuracy scores with increasing age.

Boys are more accurate than girls in throwing across the ages two through nine years. Boys, ranging in age from two to six years, excelled over girls of the same age on a moving target accuracy test (Hicks, 1930). Preschool boys from three to five years of age scored significantly higher than preschool girls on a test of throwing accuracy

(Fredrick, 1977). In testing the throwing behavior of first grade children, boys were found to be significantly more accurate than girls (Miller, 1957). Keough (1965) noted a superiority of boys over girls for children across the ages of 7, 8, and 9 years. In a throwing-for-accuracy task involving boys and girls ages 6, 7, 8, and 9 years, the boys were significantly better than the girls at each age level (Van Slooten, 1973).

Throwing accuracy increases for both boys and girls from age two years through grade 5. Improvement with age occurred regardless of the testing procedures or equipment used. In studying children aged two to six years, Hicks (1930) noted the older children had the highest mean scores. Children grouped in six month intervals from age three to five showed significant improvement from group to group (Frederick, 1977). Keough (1965), testing children across the ages of 7, 8, and 9 years and Van Slooten (1973) assessing children aged 6, 7, 8, and 9 years, both found an annual improvement in accuracy performance. Mean total scores increased from grade three to grade five when boys were tested on their throwing accuracy (Wester, 1939).

While accuracy is an important component in the mature throw, it may be possible to obtain accuracy without using good form or producing maximum force. In an accuracy test, the primary problem is for the subject to hit a target and the form used to produce the results is ignored. An investigation by Hicks (1930) provides a good example. Hicks tested throwing accuracy in children from age three to six years. He also made some general observations and comments on their style of throwing. He said, "It is impossible to say that any one style of throwing is always best, for good throwing is throwing that produces

good results" (p. 52). This is not the view that is taken here. There is a correct style of throwing. There exists a style of throwing that will result in a better throw. The reason throwing accuracy was not selected as a measure for this study is because accuracy may be obtained without necessarily requiring a mature throwing pattern.

Distance

The throw for distance has been an important tool for assessing throwing ability (AAHPER, 1965; Espenchade, 1960; Hanson, 1965; Hartman, 1943; Jenkins, 1930; Keogh, 1965; Morris et al., 1982) as well as a measure of explosive strength (Fleishman, 1964). Many investigations using the throw for distance to evaluate throwing ability have reported that (a) boys exhibit better throwing ability than girls of the same age, and (b) both boys and girls show a year-by-year improvement in distance scores. The superior performance of boys over girls in the distance throw and year-by-year improvement in distance scores for both girls and boys has been noted by Keogh, (1965); Hanson, (1965); Nichols, (1971); and Hardin and Garcia, (1982). The trend has been shown to begin with preschool children as young as three years of age (Frederick, 1977; and Johnson, 1960). Vincent (1968) reported that girls continued to improve in a beanbag distance throw from 7th grade through the 10th grade after which their performance leveled off.

Velocity

Some studies have used ball velocity at the time of release as a measure of the force that subjects can produce during the throwing motion. Most of these studies originated at the University of Wisconsin at Madison (Glassow, Halverson, & Rarick, 1965; Glassow & Kruse, 1960; Halverson, Robertson, and Langendorfer, 1982; Halverson et al., 1977;

Robertson et al., 1979). Researchers contend that the distance the ball travels is a function of the initial velocity imparted to the ball and the angle at which the ball is released. By examining ball velocity they believe they are eliminating the errors the subjects produce in the angle of release. When the release point is inaccurate, the actual distance the subject throws a ball is less than the real distance the subjects could throw the ball when the release point is correct. They reason that velocity is a more accurate measure of the force generated by the throwing motion than distance because the distance result is complicated by the angle of release whereas initial velocity is not.

While such reasoning is sound, the measurement of velocity requires a large investment of money for equipment and entails logistical problems in performing the skill. Few physical educators have a velocimeter to measure the velocity of a ball at release. Funds generally are not available for an expensive piece of equipment that will receive limited use. Another problem with velocity testing for young children is the limited visual feedback they receive from their throw. Because velocity is measured in a horizontal plane, children are instructed to throw a ball with as much force as they can against a target on a wall and not how far they can throw the ball. While children can obtain some auditory feedback from the sound of the ball hitting the wall and some kinesthetic feedback from how hard they feel they are throwing the ball, children would more likely use visual feedback and it is difficult for them to know how far they are throwing the ball. With a distance throw they can see how far it goes and understand that a harder throw will produce a longer throw.

While there are some motivational and financial problems in using velocity measurements to evaluate throwing ability, the investigations assessing throwing velocity have verified the findings of studies using the distance throw; namely, that boys throw faster than girls and that throwing velocity increases from year to year. Glassow and Kruse (1960) reported a yearly increase in velocity for girls in grades 1 through 8 at an annual rate of 3 to 4 feet per second per year. Halverson and Robertson and their associates (Halverson et al., 1977; Halverson et al., 1982, and Robertson et al., 1979) completed an eight-year longitudinal study of 22 boys and 17 girls that has been reported on three separate occasions. The children were tested in kindergarten, first grade, second grade, and seventh grade. The subjects were evaluated on both ball velocity and developmental form. They concluded that (1) the overarm throw is not fully developed by grade 7; (2) boys increased their throwing velocities at a rate of 5 to 8'/sec/yr while girls increased their velocities at the rate of 2 to 4.5'/sec/yr.; (3) girls were more stable in maintaining their relative position than the boys; (4) by grade 7 boys were 5 to 6 years ahead of the girls in developing the motor components of the overarm throw; and (5) boys reported throwing more often than the girls over the elementary and middle school years.

Since the general findings of distance and velocity throwing are similar, both the distance a ball is thrown and the initial velocity of a ball after being released can be used as valid measures of the force imparted to a ball as a result of the throwing motion. However, when the criterion of administrative feasibility is applied, the throw for distance is the measure most often used in the school setting.

Form

A fourth way to evaluate throwing is through examination of the motions used to propel the ball. Studies of qualitative skill characteristics began in the late 1920s and 1930s with Burnside (1927), Gesell (1928), H. M. Halverson (1931), Shirley (1931), McGraw (1935), Ames (1937), Wild (1938), McCaskill and Wellman (1938), and Gutteridge (1939). Early researchers were concerned with defining the age at which children exhibited certain behaviors or abilities rather than the quality of their performance. Shirley (1931) examined 25 babies during the first two years of their life and developed a sequence of intertask behaviors that lead to walking. McCaskill and Wellman (1938) set up a series of age-related tasks, each of increasing difficulty. The children were evaluated on the number of tasks they could successfully complete and compared to the standards to see if they equalled, fell below, or exceeded expectations for their chronological age.

Gutteridge (1939) established criteria for rating the performance of children on individual motor skills. She examined children during free play time and evaluated their performance on a 10-point scale. The scale was divided into four main sections of reactions. At the first level of the scale, no attempt was made when an opportunity to perform a skill was given. At the second level, a habit (skill) was in the process of formation. In the third section of the scale, the basic habit was achieved; and in the final section a skill could be performed with variations. With reference to throwing, Gutteridge concluded that at two and three years of age no child could throw a ball well, and even at four years only 20 percent of the children observed threw well, although many were practicing. From five years to five years six months

of age, however, 74 percent of the children could throw well and by the end of the same year 85 percent were proficient. Gutteridge also noted that the range of ratings in throwing was large at all ages. Even at six years of age performance in ball throwing ranged from awkward to excellent.

The now classic study of Monica Wild (1938) was the first published report of developmental patterns in performing a skill, in her case the overhand throw. After extensive analysis of the film records of 32 throwers ranging in age from 2 to 12 years, Wild suggested a four-stage developmental sequence and tentatively assigned each stage to an age level. The four stages she reported are described below:

Stage I is characterized by typical anteroposterior movements, of which there is a preliminary incipient stage with no body movement. This stage can be assigned to ages two to three or possibly up to four and is described as follows: With the reverse arm movement, the trunk extends with dorsal flexion of ankles and carries the shoulders back. The trunk then straightens, carrying the shoulders forward, and flexes forward with plantar flexion of ankles as the arm swings forward over the shoulder and down in front. Elbow extension starts early. Movements of body and arm are almost entirely in the anteroposterior plane over feet which remain in place; the body remains facing the direction of throw all the time; the arm is the initiating factor. There is trunk left rotation toward the end with the arm's forward reach.

Stage II is marked by the introduction of body and arm movements in the horizontal plane, as contrasted to the anteroposterior plane, and is assigned to ages three and one-half to five years. The whole body rotates right, then left above the feet; the feet remain together in place. The arm moves either in a high oblique plane above the shoulder or in a more horizontal plane, but with a forward downward follow-through. The elbow is much flexed; it may extend at once or later. The body changes its orientation and then reorientates to the throwing direction. The arm is the initiating factor.

Stage III marks the introduction of stepping. It is the right foot step-forward throw (right-handed thrower), assigned to ages five and six. The weight is held back on the left rear foot as the spine rotates right and extends; the arm swings obliquely upward over the shoulder to a retracted position with the elbow much flexed. The forward

movements consist of stepping forward with right foot, unilateral to the throwing arm, with spine left rotation, early turning of the whole body to a partial left facing and trunk forward flexion, while the arm swings forward either in an oblique-above-the-shoulder plane or in a sideways-around-the-shoulder plane, followed by a forward downward movement of follow-through. Elbow extension does not start at once. This throw has both anteroposterior and horizontal features.

Stage IV is the left-foot-step-forward (right-handed) throw with trunk rotation and horizontal adduction of the arm in the forward swing. This throw is the mature form and all boys from six and one-half years up exhibited it. The girls had, in most cases, attained the body and foot movements, but showed incompletely developed forms of the arm movement. Others showed decided regressions or retardations. (p. 22)

In his study of throwing accuracy in young children, Hicks (1930) also evaluated the "style of throwing." Components of the evaluation included body movement, foot action, arm movement, path of the hand, use of force, fixation of center, manner of holding the ball, and recognition of errors. He did not believe that any one style of throwing was always best, maintaining that good throwing is throwing that produces good results. Though one may speak in general of good or poor style, highly successful results are often obtained by very unorthodox styles. In Hicks' study, the highest score on the moving target test was made by a child who employed a peculiar underhanded upward throw, radically different from the delivery of any other child, and to the observer a very awkward manner of throwing. However, the focus of his study was on accuracy and not on form or distance. No developmental progression was suggested.

There was little reported research on the development of motor skills until Deach (1950) studied 43 girls and 40 boys, ages 2 through 6 years, to discover if there were, at each age level, discrete patterns of performance in several fundamental motor skills. She studied the

whole body involvement. The initial stages of development were comprised of simple actions of the arm or leg with little ability to implement adequately the demonstration trial into the desired motor act. The advanced stages approached skillful adult performance characterized by a series of complex and integrated movements. Deach concluded that the genetic development of motor skills proceeded according to laws governing physiological maturation. Patterns of performance increased in complexity and were defined in terms of stages of development rather than by chronological age. Boys were approximately one year in advance of girls and showed greater ability to move with an integrated total body pattern.

The work of Wild (1939) was the most complete work in the attempt to identify the characteristics involved in the development of a motor skill for decades until the study of movement patterns was revived by researchers at Michigan State University in the late 1960s and early 70s. Lead by Seefeldt, they examined extensive footage of film of children performing motor skills. Evaluation of the films led to the application of stage theory for analyzing motor behavior of children. Stage sequences were reported for the skills of running (Seefeldt, Reuschlein, & Vogel, 1972), jumping (Seefeldt, Reuschlein, & Vogel, 1972), throwing (Seefeldt, Reuschlein, & Vogel, 1972), catching (Seefeldt, Reuschlein, & Vogel, 1972), kicking (Seefeldt & Haubenstricker, 1974), hopping (Seefeldt & Haubenstricker, 1976a), punting (Seefeldt & Haubenstricker, 1976b), striking (Seefeldt & Haubenstricker, 1976c), and galloping (Sapp, 1980).

The five developmental stages of throwing proposed by Seefeldt and Haubenstricker (1982) are presented below:

Developmental Sequence of Throwing

Stage 1. The throwing motion is essentially posterior-anterior in direction. The feet usually remain stationary during the throw. Infrequently, the performer may step or walk just prior to moving the ball into position for throwing. There is little or no trunk rotation in the most rudimentary pattern at this stage, but those at the point of transition between stages one and two may evoke slight trunk rotation in the follow-through phase. In the typical stage one, the force for projecting the ball comes from hip flexion, shoulder protraction and elbow extension.

Stage 2. The distinctive feature of this stage is the rotation of the body about an imaginary vertical axis, with the hips, spine and shoulders rotating as one unit. The performer may step forward with either an ipsilateral or contralateral pattern, but the arm is brought forward in a transverse plane. The motion may resemble a sling rather than a throw due to the extended arm position during the course of the throw.

Stage 3. The distinctive pattern in stage three is the ipsilateral arm-leg action. The ball is placed into a throwing position above the shoulder by a vertical and posterior motion of the arm at the time that the ipsilateral leg is moving forward. This stage involves little or no rotation of the spine and hips in preparation for the throw. The follow-through phase includes flexion at the hip joint and some trunk rotation toward the side opposite the throwing arm.

Stage 4. The movement is contralateral, with the leg opposite the throwing arm striding forward as the throwing arm is moved in a vertical and posterior direction during the "wind-up" phase. There is little or no rotation of the hips and spine during the wind-up phase; thus, the motion of the trunk and arm closely resemble those of stages one and three. The stride forward with the contralateral leg provides for a wide base of support and greater stability during the force production phase of the throw.

Stage 5. The shift of weight is entirely to the rear leg, as it pivots in response to the rotating joints above it. The "wind-up" phase begins with the throwing hand moving in a downward arc and then backward as the opposite leg moves forward. Concurrently the hip and spine rotate into position for forceful de-rotation. As the contralateral foot strikes the surface the hips, spine and shoulder begin de-rotating in sequence. The contralateral leg begins to extend at the knee as the shoulder protracts, the humerus rotates, and the elbow

extends, thus providing an equal and opposite reaction to the throwing arm. The opposite arm also moves forcefully toward the body to assist in the equal and opposite reaction to the throwing arm.

During the 1970s, researchers at the University of Wisconsin-Madison also focused on developmental changes to describe the transition of children's motor skills from immature to mature performance. The Wisconsin approach to developmental sequencing was led by Lolas Halverson and MaryAnn Robertson. They believed that if there were stages (steps) in motor task development, perhaps these stages occurred only in the components of the skill rather than in the total body configuration. For example, Robertson (1982) divided the skill of throwing into five different components and established a developmental sequence for each of them. The components which she described as making up the overarm throw are (1) trunk action; (2) preparatory arm backswing; (3) humerus action; (4) forearm action; and (5) action of the feet. Thus, in throwing, a child might move ahead a stage in trunk action while retaining the same stage of arm action. Another child might stay at the same trunk action stage but progress in arm action. The developmental stages for each of the components of throwing proposed by Robertson and Halverson (1984) are presented below.

Developmental Sequence for Trunk Action in Throwing and Striking for Force

Step 1. No trunk action or forward-backward movements. Only the arm is active in force production. Sometimes, the forward thrust of the arm pulls the trunk into a passive left rotation (assuming a right-handed throw), but no twist-up precedes that action. If trunk action occurs, it accompanies the forward thrust of the arm by flexing forward at the hips. Preparatory extension sometimes precedes forward hip flexion.

Step 2. Upper trunk rotation or total trunk "block" rotation. The spine and pelvis both rotate away from

the intended line of flight and then simultaneously begin forward rotation, acting as a unit or "block." Occasionally, only the upper spine twists away, then toward the direction of force. The pelvis, then, remains fixed, facing the line of flight, or joins the rotary movement after forward spinal rotation has begun.

Step 3. Differentiated rotation. The pelvis precedes the upper spine in initiating forward rotation. The child twists away from the intended line of ball flight and, then, begins forward rotation with the pelvis while the upper spine is still twisting away.

Developmental Sequences for Backswing, Humerus, and Forearm Action in the Overarm Throw for Force

Preparatory arm backswing component

Step 1. No Backswing. The ball-in-the-hand moves directly forward to release from the arm's original position when the hand first grasped the ball.

Step 2. Elbow and humeral flexion. The ball moves away from the intended line of flight to a position behind or alongside the head by upward flexion of the humerus and concomitant elbow flexion.

Step 3. Circular, upward backswing. The ball moves away from the intended line of flight to a position behind the head via a circular overhead movement with elbow extended, or an oblique swing back, or a vertical lift from the hip.

Step 4. Circular, downward backswing. The ball moves away from the intended line of flight to a position behind the head via a circular, down and back motion, which carries the hand below the waist.

Humerus (upper arm) action component during forward swing

Step 1. Humerus oblique. The humerus moves forward to ball release in a plane that intersects the trunk obliquely above or below the horizontal line of the shoulders. Occasionally, during the backswing, the humerus is placed at a right angle to the trunk, with the elbow pointing toward the target. It maintains this fixed position during the throw.

Step 2. Humerus aligned but independent. The humerus moves forward to ball release in a plane horizontally aligned with the shoulder, forming a right angle

between humerus and trunk. By the time the shoulders (upper spine) reach front facing, the humerus (elbow) has moved independently ahead of the outline of the body (as seen from the side) via horizontal adduction at the shoulder.

Step 3. Humerus lags. The humerus moves forward to ball release horizontally aligned, but at the moment the shoulders (upper spine) reach front facing, the humerus remains within the outline of the body (as seen from the side). No horizontal adduction of the humerus occurs before front facing.

Forearm action component during forward swing

Step 1. No forearm lag. The forearm and ball move steadily forward to ball release throughout the throwing action.

Step 2. Forearm lag. The forearm and ball appear to 'lag,' i.e., to remain stationary behind the child or to move downward or backward in relation to him/her. The lagging forearm reaches its farthest point back, deepest point down or last stationary point before the shoulders (upper spine) reach front facing.

Step 3. Delayed forearm lag. The lagging forearm delays reaching its final point of lag until the moment of front facing.

Developmental sequence for Action of the Feet in Forceful Throwing and Striking

Step 1. No step. The child throws from the initial foot position.

Step 2. Homolateral step. The child steps with the foot on the same side as the throwing hand.

Step 3. Contralateral, short step. The child steps with the foot on the opposite side from the throwing hand.

Step 4. Contralateral, long step. The child steps with the opposite foot a distance of over half the child's standing height.

Robertson (1978) uses the component approach to stage theory because her interpretation of stages, based on the writing of Piagetian

theorists Flavell and Wohlwill (1969), Inhelder (1971), and Pinard and Laurendeau (1969), requires that all of the different body parts progress at the same time. She also prefers to use the term "steps" rather than "stages" in her description of developmental levels. Seefeldt and Haubenstricker (1982) agree with Robertson that all of the subroutines described in their stages do not advance as an indivisible unit. However, they have found sufficient cohesion between certain combinations of the subroutines that listing them as a 'stage' appeals to them as the least complicated way to describe a particular developmental task. Haubenstricker and Seefeldt (1986) also write that the model does not require simultaneous change in the movement patterns of all body parts from one stage to the next. However, the total body movement configuration does change and is clearly distinguishable from those in adjacent stages. Configurations that are not in full compliance with one of the described stages are considered to be in transition between stages.

Factors Affecting Throwing Distance

The ability to throw well is dependent on a variety of factors including age, gender, strength, body size, and throwing form.

Age

Of all the characteristics that subjects bring to studies of throwing, age has the most profound influence. For both boys and girls, the older children become the farther they can throw (Hanson, 1965; Hardin & Garcia, 1982; Keogh, 1965; Nichols, 1971). Improvement in throwing distance was seen in six-month intervals for boys and girls as young as three to five years old (Frederick, 1977; Johnson, 1960), and for girls through the 10th grade (Vincent, 1968).

Gender

Another characteristic associated with performance on the distance throw is the gender of the subjects. All of the studies which examined the distance throw or initial ball velocity in children found a significant difference in performance between boys and girls. Thomas and French (1985) have done an extensive meta analysis on 64 studies involving throwing and other motor tasks. They concluded that for most motor skills the performances of elementary age boys and girls are not significantly different. However, for the skill of throwing, there was a significant difference between boys and girls even at young ages. Johnson (1977), in testing 48 boys and girls between the ages of three and six years, found that boys score significantly higher than girls on measures of throwing ability. Thus, while gender is not a significant factor in most motor skills at young ages, it is in throwing performance and must be considered in studies of throwing involving children.

Strength

The selection of a strength test or battery of tests to discriminate throwing ability is clouded by two factors; the specificity of strength, and the interrelationship of different body parts during the throwing motion. A strength test is very specific in nature and must be chosen according to the muscle groups to be tested and the type of strength that is to be measured. It is also difficult to select specific muscle groups for strength testing because most of the major muscle groups of the body are involved in throwing. The arms apply most of the force used to propel the ball, but a substantial amount of force is generated by the torso, the hips and the legs (Toyoshima et al., 1974). If the limitations of selecting a strength test or battery of

tests are recognized, some discriminatory power may exist and be helpful in analyzing performance.

Strength is a major factor in the performance of many motor skills but rarely has been a good predictor for success in a skill by itself (Johnson & Nelson, 1979). An example of specificity is furnished by Berger (1962) who in a study of strength found the relationship between static or isometric strength and dynamic or isotonic strength measures to be low. He found that changes in muscle strength resulting from dynamic muscle training were more accurately measured by a dynamic strength test than by a static strength test. Simri (1974) expanded on Berger's specificity concept of strength and reports that strength is divided into three independent factors of physical fitness: namely, dynamic strength, explosive strength or muscular power, and static strength. Johnson and Nelson (1979) concluded that strength is specific, therefore it is meaningless to use one type of strength to suggest abilities in skills demanding another type of strength.

There are two ways investigators have tried to show a relationship between strength and throwing ability. One way is to use some type of overload training program on the subjects and then test if the increased strength also increases throwing velocity. The other way is to determine the degree of relationship between specific strength tests and throwing performance.

Programs for strength building in subjects of high school age and older may facilitate an increase in throwing velocity. Bagonzi (1979) studied 48 high school baseball candidates, ranging in age from 15 to 19 years. The subjects used a variety of overload training techniques including weighted baseballs, free weight training, simulative isometric

exercises and combinations of the three. The training program lasted for 18 weeks. At the end of the 18 weeks the results showed that overload training improved velocity and accuracy when compared with a control group. Rowlands (1962) assigned six college baseball players to an experimental group who were placed on a five-week weight training program and six players to a control group. A cable tension test was used to measure strength/loss of the shoulder medial rotator muscle. Throwing power was computed from the velocity of baseballs thrown over a 100-foot distance in a horizontal trajectory at a target. The program significantly improved both strength and throwing power. Sullivan (1970) had 48 university students participate in a strength training program four times a week for six weeks to determine its effect on baseball throwing velocity. The training program included a weight training group and a simulative training group which used a wall pulley to simulate the baseball throwing motion. Both programs significantly increased velocity, but the weight training program was significantly better than the simulative training program.

However, not all studies reported gains in throwing velocity resulting from a strength building program. Straub (1966) randomly assigned 48 high school boys to participate in a six-week training program using weighted balls to improve speed and accuracy. Overload training had no differential effect on either high or low velocity throwers. Control subjects who trained with regulation balls and emphasized speed and accuracy threw as fast and as accurately as subjects trained with progressive overload with an emphasis on speed or accuracy. Using a weighted ball produced no long range improvement in throwing speed or accuracy.

Barrow (1960) subjected the antagonistic muscles of 43 eighth grade boys to a six-week resistive exercise program for five minutes a day. The training program increased muscle strength and throwing accuracy, but the mean gain for throwing distance was non-significant.

Hardison (1971) trained seventh and eighth grade girls daily for four weeks in buddy resistance exercises to increase arm-shoulder strength. There was an increase in arm-shoulder strength, but the increase in arm-shoulder strength did not result in an improvement in the distance girls could throw a softball.

Williams (1985) studied 14 college baseball players of which seven participated in a weight training program three times a week for four weeks. The other seven combined long distance throwing two times a week with a weight training program. Williams found no significant differences from the pre-test to the post test for either group. He concluded that long distance throwing and weight training did not increase throwing velocity.

The four studies that did not produce significant changes in throwing performance need to be examined as to the type of strength overload used or the length of time the strength training took place. Straub (1966) provided no evidence that his subjects actually increased their strength using weighted balls. Barrow's (1960) subjects trained for only five minutes a day for six weeks while Hardison's (1971) and Williams' (1985) subjects only trained for four weeks. It is questionable whether a strength training program of only five minutes a day or one with a duration of only four weeks is of sufficient intensity or duration to produce an increase in strength. The four studies of Barrow (1960), Harrison (1971), Staub (1966), and Williams (1985)

provide evidence that strength training programs of short duration do not produce a significant difference in throwing distance or velocity. However, because of the questions about the appropriateness of the length of their strength training programs it cannot be concluded that strength training does not affect throwing distance or velocity.

While comprehensive resistance training may produce greater throwing velocity and distance, measures of strength are only moderately correlated with throwing velocity or distance. Sullivan (1970) studied 48 university students enrolled in an experimental conditioning course. He measured all subjects in throwing velocity, grip strength, wrist flexion strength and medial arm rotation strength before and after a six-week (unspecified) training program. He obtained a correlation of .42 for the relationship between strength and velocity before strength training, and .31 for the relationship after training. The hypothesis that strength is an important component of throwing velocity was not supported. Espenschade (1940) found slightly higher correlations between grip strength and throwing distance when she studied 80 girls and 85 boys over a two-and-a-half-year period beginning in the eighth grade. The girls' correlation coefficient was computed over two years; the first year it was .43 and the second year it was .60. The correlation coefficients for boys, computed for three years were .53, .71, and .41, respectively.

Other investigators, using regression analysis, have found strength related to throwing ability. Brumfield (1969) tested 35 college freshmen women on the overarm throw for accuracy and distance. The variables studied were shoulder flexibility, shoulder strength, speed of arm movement, age, height, weight, physical education background,

athletic background, gender, and number and sex of children in the family. The variables which showed significant relationships to distance throwing were shoulder strength and athletic background. Richardson (1976) tested 31 varsity high school baseball players to determine if grip strength, range of wrist flexion, and length of throwing arm were significantly related to throwing velocity. He found that grip strength was significantly correlated to throwing velocity but that wrist flexion and length of throwing arm were not. Richardson used the stepwise multiple linear regression to conclude that throwing velocity can be moderately predicted (shared variance of 36%) from grip strength measurement.

At the elite level of performance, Pedegana, and associates (1982) tested eight professional baseball players on the Cybex Dynamometer and determined that the wrist and elbow extensors have direct relationships with throwing velocity. These investigators presented a positive view of the relationship between strength and throwing velocity. They reported:

"This study shows a positive correlation between the strength of certain upper extremity muscle groups and throwing speed, a relationship which has not been clearly demonstrated in past research. The results further show lack of perfect statistical correlation between the strength of arm movements and throwing speed; however since it has been demonstrated by Toyoshima et al. (1974) that only 53.1% of throwing speed is the contribution of arm action and that throwing is a complex act involving all of the body parts the lack of correlation is explicable on that basis alone.

While this study has found, by isolating and testing each upper extremity movement and statistically correlating the strength of each movement with throwing speed, that two movements, wrist extension and elbow extension, appear to have more direct relationships with throwing speed than do the others, it is also apparent that these relationships are complex and probably interactive. However, if the exact nature of

these relationships are not altogether clear, they clearly exist and imply that modification of the strength of certain muscle groups will likely modify throwing speed" (p. 354).

How does strength affect throwing velocity or distance? Before the answer to this question can clearly be obtained, the complexity of the throwing motion must be addressed. Because one person is stronger than another does not guarantee that the stronger individual will be able to throw a ball farther. If the stronger person has an inferior throwing pattern, the weaker person could compensate for a lack of strength by using a more efficient pattern and the result could equal or exceed that of the stronger person. However, if two people had biomechanically equal throwing patterns, it would seem logical that the stronger person would have the higher velocity. This logic explains Pedagana et al.'s (1982) enthusiasm regarding their findings. They used a very small sample of select elite players. The use of elite players would make it easier to obtain a high correlation between a strength item and throwing velocity because the variety of throwing patterns is reduced dramatically. One could assume that the selection process for professional baseball pitchers would eliminate the pitchers who do not have a mature pitching form. Having all biomechanically proficient throwers greatly limits the effect of throwing patterns since they all are mature and efficient, thus allowing other factors such as strength to exert greater influence on throwing velocity. In contrast, Sullivan (1970), who used university students, and Espenchade (1940), who used eighth grade boys and girls, did not have subjects who belonged to a baseball team. They had subjects with a wider variety of throwing skill, thus the component of form could comprise a greater portion of the variability of the velocity scores. In other words, the correlation

between strength and velocity was smaller or not significant because the factor of form was not controlled.

The contribution and relationship of different body parts to throwing performance were examined by Toyoshima and his associates (1974). They measured the throwing velocity of seven adult males with five different weights of balls while limiting different parts of body movement. They found that by immobilizing various body parts the resulting velocity of the throw was subsequently reduced. The percentage of reduction was found to hold constant throughout the different weights of the balls. The mean velocity of the seven subjects using an overhand throw with a step was considered 100 percent. When the subjects were not allowed to take a step during their throw they threw the ball 84 percent as fast. When their lower body was immobilized, the velocity was 63.5 percent of the normal throw. Immobilization of the upper body reduced the velocity to 53.1 percent. When the upper arm was placed on the arm of a chair and immobilized, the velocity of the throw was reduced to 42.6 percent of the normal throw. Based on their findings, Toyoshima and his associates accorded 53.1 percent of the total throwing velocity to arm action and the remaining 46.9 percent to the step, hip rotation, and trunk rotation. These investigators reported that their results match those of Broer (1969) who, in a study of two women throwing a tennis ball, concluded that approximately 50 percent of the velocity of the overhand throw resulted from the step and body rotation, while the remainder came from shoulder, elbow, wrist, and finger action.

Toyoshima et al. (1974) also measured the angular velocities of the forearm during a normal throw and forearm throw. In normal throwing,

the results were 31.14 radians per second; in forearm throwing, they were 15.57 radians per second. They concluded:

"It was verified, therefore, that the extension of the elbow joint was performed at a higher speed in normal throwing than in the activity of maximal voluntary effort using the elbow joint. This indicated that the forearm was being swung like a whip by the rotary actions of other parts of the body, such as hip, trunk, and shoulder. Moreover, the greater the radius of rotation, the greater will be the production of speed in these ball-throwing situations.

"In summary, it appeared that the contribution of the extension of the elbow joint to the speed of the ball did not result only from the power caused by voluntary muscular contraction of the triceps brachii, but also from the torque produced by rotation of the body. The radius of rotation of the forearm in the flipping motion was increased by body rotation, thus resulting in a greater speed. It therefore would seem that the contribution of the elbow joint in normal throwing performance may be less than the 42.6% calculated in this study; as a matter of fact, a larger percentage of the velocity of the thrown ball resulted from the body rotation. Furthermore, it is interesting to note that the rapid arm action acts not on the basis of conscious muscle contraction, but from the physical phenomenon and reflection of the neuromuscular system" (p. 174).

Body size

In general skill testing, investigators have found low relationships between the performance of fundamental skills and height and weight. Keogh and Sudgen (1985) wrote:

"The development of maximal performance has been studied primarily in terms of structural changes, except for the development of muscle in relation to functional strength. The principal finding is that structural differences among children of the same chronological age cannot predict maximal movement performance as defined here. Few of the measures of height, body proportions, body composition, and physique for children at age 6 correlate substantially with their maximal performance scores for running, jumping, throwing, and similar movement tasks. Malina and Rarick (1973), in a critical review of related literature, concluded that 'performance in motor skills during elementary school ages is largely unaffected by

body build and constitutional factors, except at the extremes of the continuum' (p. 150, italics added). They acknowledge that physique and related structural characteristics can limit or enhance performance but are not good predictors of maximal performance scores (also see Malina, 1975)" (p. 254).

"Despite the generally neutral findings, structural differences probably are important to maximal performance for the movement skills we are reviewing here. The problem seems to be in matching specific structural characteristics to specific task requirements. For example, it seems too much to expect that a general measure of physique will predict a specific movement achievement. But the general physique category of mesomorphy does combine the body proportions and composition that should contribute to better performance in many play-game and athletic skills. We should analyze task requirements more carefully to find specific aspects of physique that contribute to maximal performance. We also need to include functional characteristics, which may be more important. Asmussen (1973) stressed the functional use of strength. This means that we must find ways to assess the coordination of movement control. Some individuals probably are better equipped than others are to coordinate movement parts, in summing force, although they can make great improvement with good instruction. Our comments here do not change our conclusion that structural differences among children of the same chronological age do not predict maximal performance" (pp. 257-258).

The relationship of biological variables to throwing performance has been investigated. Johnson (1960) administered a number of performance tests on fundamental skills to 2,459 boys and 2,195 girls in Grades 1 to 6. In addition to the skill testing, he collected data on the ages, heights, and weights of the subjects. He concluded that the age, height and weight of boys and girls in grades 1 to 6 appear to have low relationships with performance on tests of fundamental skills. Frederick (1977) evaluated the throwing ability of 3, 4, and 5 year-old black and white girls and boys, but found no significant relationships between weight, height and throwing performance level. Espenschade (1940) studied 80 girls and 85 boys for a two-and-a-half-year period

beginning in the eighth grade. She evaluated the relationship between weight, height, stem length/height, and stem breath/length with the distance throw, but all the relationships were non-significant.

Nelson, Thomas, Nelson, & Abraham, (1986) examined gender differences in children's throwing performance, including biological and environmental variables. They studied 100 kindergarten children, 48 girls and 52 boys. Throwing performance was evaluated by throwing a beanbag for distance. The form of the throw was evaluated using the scales developed by Robertson (1984) for the trunk and feet. Biological factors measured were height, weight, body mass index, ponderal index, skinfolds (triceps, subscapular, suprailiac, and calf), body diameters (biacromial, bi-iliac, biepicondylar width of the humerus, and bicondylar width of the femur), girths (biceps and calf), arm length, forearm length, and somatotype. Environmental factors consisted of whether the child had older siblings, an adult male(s) in the home, and whether the child played with other children.

In a forward stepwise regression only two variables significantly predicted throwing performance for boys, estimated leg muscle and shoulder/hip diameter ratio. However, they accounted for only 18 percent of the variance in throwing. For the girls, two biological (estimated arm muscle and shoulder/hip diameter ratio) and two environmental variables (older brother and playing with other children) were significant predictors of throwing performance. These variables accounted for 48 percent of the throwing variance. Four variables that predicted throwing distance regardless of gender were joint diameters, shoulder/hip ratio, sum of skinfolds, and playing with other children. The linear composite accounted for 41 percent of the variance (R^2).

Nelson and associates (1986) then employed an ANCOVA using gender as an independent variable, throwing for distance as a dependent variable and the three biological variables (joint diameters, shoulder/hip ratio, and sum of skinfolds) previously identified as covariates. The results of this analysis indicated the overall test of the model was insignificant. When biological factors were not taken into account, girls' performance was 57 percent of that of the boys', but when they were considered, girls' performance was 69 percent of that of the boys'. Boys differed from girls in certain specific growth characteristics—boys had significantly greater diameters for the elbow and knee, and more estimated arm muscle while the girls were significantly more endomorphic and had a greater sum of skinfolds, indicating more fat.

The results of this study support the prediction of Thomas and French (1985) that prior to puberty, throwing is a task in which some of the small differences in specific growth characteristics between boys and girls influence performance. Having a more robust skeleton (larger joint diameters), a greater shoulder/hip ratio, a smaller sum of skinfolds, and more estimated arm muscle positively influences performance in throwing for distance. This does not mean that biological variables are the major contributors to performance differences in throwing, they are not. However, they do appear to make some contributions.

Results of other investigations regarding the influence of biological factors on throwing performance are mixed. Sanders (1977), when studying college baseball players, found that age, height, weight, and length of arm span were not significant as predictors of baseball

throwing velocity. Kang (1982) studied 8th grade boys and girls and determined that hand size had no significant effect upon throwing performance. Bowne (1960) selected 42 high school girls, one-third of whom were average throwing skill ($v=42-46'$ /sec), one-third of medium skill ($v=50-54'$ /sec), and one-third highly skilled ($v=58-62'$ /sec). She took numerous structural measures including lengths for the hand, shoulder, pelvis, foot, stature, sitting height, trunk height, leg, upper arm, forearm, and thigh. She concluded that it was not possible to distinguish between velocity groups on the basis of the scores for any structure length variable. Richardson (1976) tested 31 varsity high school baseball players on arm length, wrist flexion, and throwing velocity. Arm length and wrist flexion were not significantly correlated with throwing velocity.

Seils (1951) tested first, second, and third grade boys and girls on a variety of motor skills and physical growth variables. Very low insignificant relationships between age, height, weight and throwing ability were found. However, a correlation of .42 for the boys and .38 for the girls was obtained between throwing performance and a measure of skeletal maturity. Eoff (1985) studied the throwing ability of first and fourth grade boys and girls as represented by velocity, distance, accuracy, and quality of throw and their relationship to the structural-maturational variables of height, weight, arm length, and subcutaneous fat. Arm length was predictive of the throwing ability of first grade girls. Arm length and weight were predictive of the throwing ability of fourth grade girls. All of the structural and maturational variables contributed to the prediction of throwing distance for both first and fourth grade boys.

Mahmoud (1979) evaluated girls and boys ages four to six years to determine the relationship between throwing distance scores and some selected temporal and kinematic factors as well as certain anthropometric measures, and to determine the best combination of factors for predicting throwing distance and improvement based upon distance gain. The following variables were measured: height, weight, upper arm, forearm, and hand and forearm length. Film analysis yielded force time, angle of ball release, velocity of the ball at release, as well as segment orientation and stride length. Mahmoud reported significant relationships between the distance a ball was thrown and sex, age, height, hand and forearm length, angle of release, velocity of the ball, and wrist angle on the pre-test. On the post-test a significance relationship was reported between the distance a ball was thrown and sex, angle of release, stride length, velocity of the ball and improvement; but the anthropometric measures of height, and hand and forearm length were not significant.

The inconsistencies associated with the significance of structural variables with throwing distance leads to the conclusion that structural variables alone are not sufficient to differentiate between good and poor throwers. This is especially true of subjects in grade seven and older. Some structural variables of young children (age 4 to grade 4) have been found to have predictive or significant structural relationships with throwing ability. A possible explanation is that structural variables are indicative of the total maturation of the young subjects resulting in greater strength and a more mature nervous system.

Form

Biomechanical factors found to be associated with a better throw are an increase in the range of trunk rotation (Bowne, 1960; Ekern, 1970; and Singer, 1961); a decrease in the medial rotation of the arm (Bowne, 1960; and Ekern, 1970); better ratings of form for trunk and foot action (Nelson et al., 1986); rapid sequential acceleration and deceleration of trunk and arm segments prior to release (Atwater, 1970; and Deutsch, 1969) an increase in stride length (Deutsch, 1969; Ekern, 1970; and Schutzler, 1980); a greater forward flexion at the hip joint at the point of release (Ekern, 1970; and Lyon, 1961) and a greater range of movement in contributing joints (Singer, 1961).

An increased range of trunk rotation was found to be associated with a better throw when Bowne (1960) selected 42 high school girls, one-third of whom were average throwing skill, one-third of medium skill, and one-third highly skilled. In evaluating the subjects' form she noticed they increased velocity when there was an increase in the range of trunk rotation. Singer (1961) in her four-year longitudinal study of four girls also reported that subjects with greater throwing velocity showed a greater rotation of their torso. Ekern (1970) compared the throwing performances of boys and girls (2 each) in grades 2, 4, and 6 on the basis of selected measures taken from film records of the overarm throw with a particular emphasis on the preparatory phase of the throw. Selected body levers were studied noting the time of entrance, duration of action, moment arm lengths and ranges of movement. The position and direction of movement among selected body parts, the path of the ball, the center of gravity changes of the body and the bases of support were investigated. The results of this study

indicate that the boys in the preparatory phase used greater reverse spinal rotation than the girls. They also used pelvic and spinal reverse and forward rotations more effectively.

Bowne (1960), in her study of 42 high school girls grouped according to their throwing velocity, noticed they increased velocity when there was a decrease in the medial rotation of the arm. Ekern (1970) in her comparison of the throwing performances of boys and girls (2 each) in grades 2, 4, and 6 also reported a decrease in time used for medial rotation of the humerus in boys compared to girls and when older students were compared to younger ones.

Robertson's (1984) components of trunk and foot action (corresponding with trunk rotation and stride length) were also used to compare good throwers with poor ones. Nelson et al. (1986) evaluated the throwing differences in boys and girls at 5 years of age. One of the means by which they evaluated the throwing performance was determined by components in trunk and foot action as proposed by Robertson. The correlations were moderately high between distance thrown and ratings of form for trunk rotation (.67) and foot action (.64).

Another means for evaluating good form is the determination of the sequential acceleration and deceleration of trunk and arm segments prior to release. Atwater (1970) examined three groups of subjects (5 in each group): skilled men (college baseball players $v = 110-125'$ /sec), skilled women ($v = 70-80'$ /sec), average women ($v = 40-50'$ /sec). She found that the subjects with the fastest ball velocity at release were those with the most rapid sequential acceleration and deceleration of trunk and arm segments prior to release. She concluded that while the range and sequence of joint actions was similar for all skilled men and

skilled women, the rate at which these actions took place was faster in men than women. Deutsch (1969) took three groups of five women representing expert, average, and poor levels of throwing to determine the mechanical and muscle action differences underlying skill in throwing a baseball for speed both overhand and underhand. Stride length, horizontal and vertical displacement of the right hip and shoulder, body lean and right arm angle at the left foot down and last ball contact positions, and ball speed were derived graphically from successive movie frames. Overhand ball speed correlated significantly with stride length and the difference in right arm angle during the throw. Throwing fast apparently depended on successive and concentrated hip, shoulder, and hand (ball) acceleration of sufficient intensity for the reaction to produce negative acceleration in the preceeding segment.

The advantage of an increase in stride length was noted by Deutsch (1969) in a study of college women when overhand ball speed correlated significantly with stride length. In a study of boys and girls in grades 2, 4, and 6, Ekern (1970) noted that both boys and older children used larger working bases with more advantageous foot placement. Schutzler (1980) compared stride length to velocity between groups of major league, triple A and college pitchers. He found velocity was significantly different between groups but stride length was not. But when the 15 fastest pitchers were compared with the 15 slowest pitchers irregardless of their group, the ratio of stride length/height was significantly greater for the faster pitchers.

A greater forward flexion at the hip joint at the point of release was noted to be a characteristic of both highly skilled throwers and developing throwers. Lyon (1961) compared one major league pitcher with

seven University of Wisconsin pitchers and found that the subjects with the greatest forward flexion at the hip joint had the highest velocities. Ekern (1970) in her study of second, fourth, and sixth grade boys and girls also noted that the boys and older students exhibited greater forward trunk inclination.

Proper form is not guaranteed as a function of age or maturation. Halverson, Robertson and Langendorfer (1982) reported that the overarm throw was not fully developed in male or female seventh graders. Leme (1973) tested mature females and discovered that similar movement patterns are used in the development of throwing regardless of age. Less than complete development of throwing exists in some adults. She also noted that one subject regressed in throwing velocity while learning to use a new, more developed, throwing pattern. Dusenberry (1952) also noticed some decreases in distance due to changes in the manner of throwing.

Instruction

Providing instruction in throwing has produced mixed results, sometimes even in the same study. Hoffman (1969) taught first through third grade boys and girls 30 minutes a day for a six-week period with many opportunities for individual help. Significant improvement was reported for first grade girls and second grade boys. Greater, but non-significant, improvement was reported for second grade girls and third grade boys and girls. No gain was reported for the first grade boys. Luedke (1980) instructed second and fourth grade students in two different programs. They included basic instruction and instruction emphasizing increasing range of motion (IRM). The IRM instruction

significantly improved the velocity scores of second graders, but not fourth graders.

Teaching has produced increases in throwing ability in preschool children, in children in grades three through seven, and in college women. Dusenberry (1952) paired fifty-six 3, 4, 5, 6, and 7-year-olds into control and treatment groups on the basis of age, gender, race, and the average of five throws. The treatment groups met 2 times a week for 3 weeks. He concluded that at a seven per cent level of significance, the specific training increased learning over maturation and gym practice. He also noted that boys improved more than the girls and that the older children (5-6) profitted more from the instruction than did the younger children (3-4). Mahmoud (1979) reported that preschool children exhibited significant changes in throwing distance, form and stride length from pre- to post-test after instruction for 15 minutes a day, 3 days a week, for 4 weeks. Potter (1963) trained college women by two methods. One group practiced throwing and the other was trained isometrically. The women trained 3 times a week for 5 weeks. The throwing group showed a significant mean gain in throwing distance over the isometric group.

On the other hand, several investigations failed to demonstrate improvement in throwing due to teaching for subjects ranging from kindergarten through eighth grade. Halverson et al. (1977) gave kindergarten students 120 minutes of guided practice over an eight-week period and reported that throwing velocity did not significantly change. Robertson et al. (1979) also evaluated these same children as second grade boys and girls and reported that there was no evidence of long term effects due to the instructional program they received in

kindergarten. Nichols (1971) instructed a group of four to seven year olds, five minutes a day, two days a week, for six weeks and reported no significant difference between the distance throw of this group and a control group which had regular free time. Deatrick (1977) divided seventh grade girls into three groups for a five-week training period. Group I trained on the Apollo Exercisor, while group II trained by practicing softball throwing and group III maintained its regular physical education program. She reported a non-significant relationship between the training programs. Dohrman (1964) conducted a study with eight-year-old boys and girls. He divided 100 students into two treatment groups. Each group was to receive special training in throwing and kicking. One group received the training during the fall while the second group participated in the training during the spring. He concluded that throwing and kicking programs, in addition to regular physical education, do not result in greater improvements in throwing or kicking ability.

In an effort to determine the effectiveness of various programs of motor skill instruction for three- and four-year-old children, Miller (1978) compared four different programs. She compared a traditional style of teaching, a teaching program which also included parental help, a free play program in which the children used the same equipment but were not exposed to any formal program of instruction, and a control group which had no access to the equipment but was used to control for the effects of maturation. Miller found that the traditional and parent instructional groups performed significantly better than the free play group, indicating that programs of directed practice and instruction

were more effective than programs of free play in increasing fundamental skill level of young children.

Glassow and associates' (1965) two-year, longitudinal study included overhand-throw ball velocities for all children and filmed content measures for a randomly selected group from three grade levels. First-, third-, and fifth-grade records were obtained following a year in a special instructional program. Second-, fourth-, and sixth-grade records on the same children were collected after a second year in the program. The authors reported no consistent differences between gains in overhand ball velocities for the experimental groups and those made by previous children in school used for control comparison. When throwing form was considered, however, the children did not show steady improvement across ages in all groups. For instance, after two years in the special instructional program, a higher percentage of second- and fourth-grade girls used a ninety degree preparatory turn than the older third- and fifth-grade girls did after one year in the program. Also, a greater percentage of second-grade boys and girls took a forward step and had a longer stride than the older third-grade children. Apparently the special program did have an influence on the throwing ability by improving the throwing form of the experimental groups, a finding not evident when only the velocity achievement scores were examined.

In summary, instruction can play an important role in improving throwing ability. However, because of the complexity of throwing, the readiness and the motivation of the students, and the length and quality of the instruction, it is important to realize that not all instruction will have a positive influence on every aspect of throwing ability every time.

Justification of Testing Procedures

Strength

The hand grip test was chosen because it is not directly related to body size and is the best single indicator of body strength. In addition, grip strength has been found to be related to throwing performance (Espenschade, 1940; Richardson, 1976). On the other hand, grip strength is a measure of static strength rather than the explosive strength or muscular power used in the throw for distance. Thus a second test, one measuring dynamic strength was also used. The best test measuring extensor strength of the arm and shoulder muscles was the push-up. Shoulder strength was found to be significantly related to throwing distance in college freshmen women (Brumfield, 1969).

Grade versus Age

Hanson (1965) evaluated boys and girls from grades 1 through 6 on age, height, weight, intelligence and numerous motor performance tests. She examined the interrelationships between the different variables and concluded that the within grade performance of children was consistent enough to be evaluated as a group. She found low single variable interrelationships between age, height, weight, intelligence and motor performance tests. Relationships derived from multiple correlations (age, weight, height, and intelligence) (age, height, and weight) were significantly low to negate the need for classification indices to evaluate the motor performance of children within a single grade level.

Modeling

The formation of a proper modeling procedure for the subjects was primarily motivated by Bandura's (1977) theory of self-efficacy.

Bandura's theory of self-efficacy is defined as the strength of a person's conviction that he or she can successfully execute a behavior required to produce a certain outcome. In this case, self-efficacy would entail that the children would have enough confidence in their ability to throw effectively that they would give their best effort in their distance throw. In the development of self-efficacy, Feltz, Landers, and Raeder (1979) examined the effectiveness of participant, live, and videotape modeling on enhancing self-efficacy in the learning of a high-avoidance springboard-diving task. They found that the participant-modeling treatment produced more successful dives and stronger expectations of personal efficacy than either the live-modeling or videotape-modeling treatments. However, no differences were obtained between the live-modeling and videotape-modeling treatments. Gould and Weiss (1981) tested the effects of model similarity and model talk on self-efficacy and muscular endurance. Specifically, subjects who observed a model of similar sex perceived to be similar in athletic ability demonstrated greater muscular leg endurance than subjects who observed a dissimilar model of the opposite sex perceived to be superior in athletic ability.

It was determined a videotaped model would be an effective modeling procedure for the study, because Feltz et al. (1979) did not find a difference between live-modeling and videotape-modeling treatments. The videotaped model was a consistent model, providing the same information to each of the participants.

Both a male and female student model were videotaped because Gould and Weiss (1981) showed a significant difference in performance between subjects who viewed similar and dissimilar models. A sixth grade boy

and girl, both of whom could throw using a mature pattern, were chosen to demonstrate all of the testing procedures on videotape. Thus each of the subjects could watch a model of the same gender, nearly the same age, perform all of the testing procedures. The videotape would also make certain that the same information would be provided to each of them.

CHAPTER 3

METHOD

The purpose of this investigation was to investigate the relationship of throwing form as described by a developmental sequence and throwing achievement as defined by the distance a ball can be thrown. To accomplish this, the throwing motion of the throwers was tested as well as the distance they threw the ball.

Subjects

Students in kindergarten through fifth grade at a private Christian elementary school provided an available sample for this study. All the students participated in the study unless they were physically disabled or elected not to participate. The subjects came from predominantly white, middle class, Protestant families residing in a small Midwest community.

The procedure for participating in the study included the signing of a consent form by the parent and a consent form by the student prior to testing. Parents of the students were contacted by letter explaining the rationale for the testing and the procedures that were to be used. (A copy of the parent consent form is located in Appendix A.) The students were given the opportunity to choose whether or not to participate in this study after previewing a demonstration of the testing procedures on videotape. Those who decided not to participate were returned to their classroom and excluded from testing. Children who decided to participate signed a consent form. (See Appendix A.)

The sample size and the number of drop outs for each grade and sex are listed in Table 1. Of the 307 subjects agreeing to participate, four were dropped from the study because they had incomplete data. The physical education teacher completed a subjective evaluation of the students who elected not to participate in the study. Most of them were rated below average in athletic ability and, more importantly, below average in self confidence regarding their physical abilities. In examining the data, more than half of the drop outs were girls in the kindergarten, first, or second grade. It appears some of the younger girls were reluctant to put themselves in a situation they perceived as competitive and male-orientated. The three boys in the fourth grade who dropped out had joined together and made a group decision not to participate in the study.

Table 1

Total Number of Participants and Dropouts in the Study by Grade and Gender

Grade	Males		Females		Total Participants
	Participants	Non Participants	Participants	Non Participants	
K	27	3	19	5	46
1	29	1	31	5	59
2	19	0	28	9	47
3	22	0	28	2	48
4	22	3	26	1	48
5	32	0	24	1	55
Total	151	7	156	23	307

Testing Procedures

The testing procedures included calculating the ages of the subjects based on birthdates obtained from school records, measuring their height and weight, and dividing them into squads based on grade and gender which rotated through five testing stations. Information concerning height and weight was collected within two weeks of the administration of the test for throwing ability.

In order to facilitate testing and to increase efficiency, the subjects were placed in squads. The squads contained four to six subjects of the same grade and gender. The squads rotated as a unit through the various stations. When the subjects were placed into squads, they were informed that they were not competing with anyone else in their squad nor were the squads competing against each other. They were just told to do their very best on the tests. They were asked to encourage the members of their squad to perform their best at each station. They also were reminded to do the best they possibly could and not to compare their performance to anyone else's performance.

The five stations were as follows. The subjects received instruction regarding the procedures used to test their throwing ability and strength at station 1. The subjects participated in an organized warm-up at station 2. The actual testing of the subjects' throwing ability occurred at station 3. Grip strength testing occurred at station 4. Finally, the subjects were tested on their ability to do push-ups at station 5. After the students completed the testing at station 5, they were excused to return to their classroom.

Throwing Ability

Throwing ability was tested in two ways, the distance the ball traveled in the air and the form that was used in throwing the ball. Both of the variables were simultaneously tested, throwing distance was measured immediately after the throws were made, while the form was determined via examination of a video tape of each subject's throws.

Testing the throwing ability of the children required three steps which were accomplished at three stations. The subjects were provided an explanation and demonstration about the testing procedures so they understood what was required of them. This was accomplished by viewing a videotape at station 1. The students were allowed time to warm-up their throwing arms and practice throwing at station 2. Finally, the subjects participated in the actual testing at station 3 where they threw the ball as far as they could and were videotaped for future evaluation of the stage of throw they used.

The method chosen to explain the testing procedure was a videotape of a sixth grade child demonstrating the different activities involved in the study while an explanation of each of the testing procedures was given. Two videotapes were made; one with a male model for the boys to view and one with a female model for the girls. The modeling was motivated by the theory of self-efficacy (Bandura, 1977) and the finding that the more similar the model the greater the performance (Gould & Weiss, 1981). A videotape was used instead of a live model because videotape-modeling is as effective as live-modeling (Feltz et al., 1979), the demonstrations and instructions would be uniform across gender squads, and the different stations could be viewed without physically moving the subjects about.

In preparation for the distance throw, the subjects watched a videotape demonstration of the testing procedure. The videotape showed a sixth grader demonstrating a mature (stage 5) throwing pattern who was the same sex as the subjects who were going to perform the distance throw test. The demonstrator on the videotape told the subjects how to perform the test. Emphasis was placed on taking their time and throwing the ball as far as possible before it bounced. After viewing the videotape, the subjects were given the opportunity not to participate in the study.

After they watched the videotape, the students who elected to participate in the study proceeded to the warm-up station. The warm-up took place outside the gym next to the testing station. To warm up, they threw a ball against the school wall. The warm-up consisted of a minimum of 10 and a maximum of 15 throws. The subjects were told to throw the ball as hard as they could on their last three warm-up trials. They used a 9-inch rag ball during warm-up as well as during the testing. After the subjects had warmed up, they proceeded to the throwing station and waited until the preceding group was finished throwing.

At the throwing station, the subjects' throwing ability was assessed by the horizontal distance they could throw the ball in the air and the stage they used in making the throw. The instructions to the subjects were, "From this line on the ground, (pointing to the restraining line) throw the ball as far as you can that way (pointing to the direction they were to throw the ball) in the air." The children threw from behind a restraining line. Their throws were measured from the restraining line to the spot on the ground where the ball landed.

The longest of the three throws the subjects made was used as their score. The longest of the three throws was used in evaluating an individual's maximum performance because maximum performance is commonly used in sports performance.

Three individuals were needed at the throwing station: a camera operator (and recorder), the test administrator, and a person to identify and measure the point where the ball landed. The camera operator was responsible for videotaping the thrower. The test administrator was at the restraining line making sure the subjects were throwing in the correct sequence and that they understood the directions given to them on the video. He had the subjects verbalize what they were to do to verify that they understood the directions. He also cued the camera operator when the subject was ready to throw. The third member of the administration team was positioned in the landing area. Markers, identified with a number and a letter to designate the thrower and the number of the throw, were used to mark the spot where the balls landed. After each squad completed its throws, this person and the test administrator measured the distance the ball traveled in the air to the nearest foot. The camera operator recorded the distance scores on a score sheet according to subject number and the number of the throw.

The subjects' throwing performance was recorded on videotape for each trial. The developmental stage the subjects used in achieving their best distance throw was determined. The stage was not determined during the throw itself but on review of the videotaped throws. The investigator's assignment of stages was verified by faculty experts from Michigan State University.

Strength

The rationale for including strength tests to help evaluate the distance throw is that given two persons of similar height, weight, age, and throwing form the one who is stronger should throw the ball farther. The relative strength of the throwers might affect their performance. The strength tests used in the investigation included a static test—hand grip, and a dynamic test—push-ups. These two measures were selected because of their potential contribution to throwing performance as well as the feasibility of their use with elementary school children.

The hand dynamometer test was used to assess dominant hand grip strength. The hand used for throwing was noted during the throwing procedure and that hand was tested for grip strength. When the hand used for throwing was not consistent from trial-to-trial, the hand used for the longest of the three throws was considered the dominant hand.

In the administration of the hand dynamometer test, the tester set the pointer to zero and placed the dynamometer in the subject's hand. The tester then adjusted the handle of the dynamometer so the first joint of the index finger formed a 90 degree angle as it rested on top of the handle and it felt comfortable in the subject's hand. The subjects were encouraged to squeeze as hard as they possibly could. They squeezed as sharply and steadily as possible, making certain that no part of the arm touched the body. Three trials were taken with a minimum rest period of a one minute between squeezes. The three trials were recorded to the nearest one-half kilogram. The score for each subject was the mean of the three trials. The same dynamometer was used for all subjects.

The subjects were tested on the number of push-ups they could do during a 30-second period. A piece of foam rubber 4 inches thick, 8 inches wide and 5 feet long was used to help standardize the push-up procedure. The foam rubber was placed underneath the subjects with their arms straddling it. The subjects started by lying on the foam. A push-up was counted every time the subjects pushed their bodies up so that their arms were fully extended and their knees were clear of the foam rubber. On the downward phase of the push-up, part of the head (for example the forehead, nose or chin) and part of the chest or abdomen had to touch the foam before another push-up could be counted. A subject's score was the number of full extensions completed during the 30-second time period. A video recording was taken of each group so that performances could be scored at a later time. A description of the stations used in the study, the number of individuals needed to operate each of the stations, and the duties of the individual personnel are identified in Table 2.

Other Data

The subjects' grade and gender were noted and recorded on the sheets used to record their throwing distance. The subjects' height and weight were obtained and recorded within two weeks of the testing. Standing height was measured with the students standing fully erect in stocking feet and stretched to the fullest height while keeping the heels flat on the floor. The students stood against a wall while the tester placed a wooden triangle with a right angle against the wall and on top of the subjects' head. Standing height was read to the nearest quarter inch from a tape measure fixed to the wall. The subjects were

Tab

Tes

#1

#2

#3

#

#

Table 2

Testing Personnel and Their Duties

Station	Workers	Duties
#1 Video	Supervisor	Supervise showing the video tape on the instructions of the throwing procedures. Make sure the correct one is played and the students are listening and understand the instructions.
#2 Warm-up	Supervisor	Make sure students are throwing so they have a proper warm-up and keep other students finished with the warm-up in line, not watching the thrower.
#3 Throwing	Test Administrator	Make sure subjects understand instructions and exhort them to make their best throw. Hold the end of the measuring tape in the correct place.
	Camera Operator	Film the thrower, making sure the entire body is filmed. Record the distance of the throws when the squad was finished.
	Spotter	Mark the place where the ball hits the ground with the correct marker and help measure the distance.
#4 Dynamometer Tester		Demonstrate the procedure of the hand dynamometer and record the scores.
#5 Push-ups	Tester	Give instructions for the proper push-up, time the allotted 30 seconds, and count and record the number of push-ups.

weighed to the nearest one-half pound on a balance scale without shoes while in their daily school clothes.

Treatment of Data

Means and standard deviations for the independent and dependent variables were calculated. The variables included throwing hand grip strength, push-ups, developmental throwing stage, height, weight, age, and the distance the ball was thrown. In addition, the means and standard deviations on these variables were computed for each grade, and for gender within each grade.

Pearson correlation coefficients were calculated to determine relationships between developmental throwing stage, hand grip strength, push-ups, height, weight, age, and the distance the ball was thrown. Three intercorrelation matrices were generated, one matrix for all the subjects and one for each gender. In addition, correlation coefficients were obtained to determine test/retest reliability of the push up and hand dynamometer strength tests.

Three stepwise multiple regression analyses were run to predict throwing distance based on the variables of age, grade, stage, height, weight, push-ups, and hand grip strength. Regression equations were generated for all the subjects combined, for the girls, and for the boys. The regression equations also provided appropriate covariates for the ANCOVAs that were run. Any variables which entered and remained in the final equations were considered important variables which had to be accounted for either as main effects or as covariates for the gender of the subjects involved in the ANCOVA.

To test the first hypothesis, that for each grade level boys will be able to throw the ball farther than girls, a 2 X 6 ANCOVA was run

using gender and grade as the two factors. The variables that entered the regression equation for all subjects combined, except for gender and grade, were used as covariates in the ANCOVA.

The second hypothesis was that members of the same gender in an older grade will be able to throw the ball farther than those in a younger grade. This hypothesis was tested by running a one-way ANCOVA using grade as the factor with the appropriate covariates as determined by the appropriate regression equation.

Testing the third hypothesis, that children of the same grade who have a more mature form of throwing as measured by developmental sequence will be able to throw the ball farther than children at a less mature stage of throwing, required a number of steps to test. First, a stage by grade by gender cross tabs program was run to determine the frequency of subjects in each cell of the matrix. Blank cells were noted and cells were collapsed based on the findings. Next, separate ANCOVAs were run for the boys and girls using developmental stage as the independent variable with appropriate variables as covariates.

For all of the ANCOVAs run, the main effects and two-way interactions were examined. When the main effects were significant, the post hoc multiple comparison method of Scheffe was applied.

CHAPTER 4

RESULTS AND DISCUSSION

This study investigated the relationship between developmental stage of throwing and the distance a ball was thrown by children. In addition, this research effort examined the effect that gender, height, weight, age, grade, push-ups and grip strength had on a distance throw.

In this chapter, the results and discussion will be presented together in five sections. First, descriptive statistics of the variables will be reviewed. Second, findings from regression analyses to determine the predictability of throwing distance and to identify covariates will be discussed. Third, the results from the analyses of variance will be presented and examined in relationship to the effect of gender and grade on throwing distance. Fourth, the results from the analyses of covariance will be reviewed with regard to the effect of stage on throwing distance. Finally, the findings will be discussed and compared to the results of previous investigations.

Descriptive Statistics

The means and standard deviations of all the variables were calculated to provide an overview of the relationships between the variables within and across the different grade and gender groups. The tables containing the means and standard deviations for throwing hand grip strength, push-ups, height, and weight are located in Appendix B (Tables B-1 through B-4).

An examination of the difference between the mean age of the boys and girls for each grade showed that the chronological age of the boys was slightly greater than that of the girls in every grade, but only in the fourth grade was the difference more than 2 months (Table 3). A t-test comparing the ages of boys and girls showed that only in the fourth grade was there a significant difference between the ages of boys and

Table 3

Means, Standard Deviations, and t-values for the Chronological Age of the Subjects (in months)

Grade	Total/ Gender	Means	Standard Deviation	Cases	t
KINDERGARTEN	TOTAL	76.93	3.81	46	1.156
	BOYS	77.26	3.51	27	
	GIRLS	76.47	4.26	19	
1ST GRADE	TOTAL	88.68	4.28	59	.994
	BOYS	89.24	3.76	29	
	GIRLS	88.13	4.73	30	
2ND GRADE	TOTAL	99.70	4.71	47	.987
	BOYS	100.53	4.85	19	
	GIRLS	99.14	4.62	28	
3RD GRADE	TOTAL	111.79	4.05	48	1.417
	BOYS	112.68	4.16	22	
	GIRLS	111.04	3.87	26	
4TH GRADE	TOTAL	124.44	4.30	48	2.060*
	BOYS	125.82	3.40	22	
	GIRLS	123.27	4.68	26	
5TH GRADE	TOTAL	134.64	5.48	55	.828
	BOYS	135.16	6.26	32	
	GIRLS	133.91	4.17	23	
ALL GRADES	TOTAL	106.27	20.54	303	
	BOYS	106.99	21.67	151	
	GIRLS	105.56	19.45	152	

* t is significant $p < .05$

girls. Since only one of the grades was significantly different in age between the boys and girls it was decided that grade would be an appropriate means for dividing the subjects.

The mean performance of the subjects in the distance throw increased for each of the grades tested (Table 4). However, when examining the gender groups separately, the same trend existed but an increase did not occur between each grade level. The boys' performance

Table 4

Means and Standard Deviations for the Distance Throw (in feet)

Grade	Total/ Gender	Means	Standard Deviation	Cases
KINDERGARTEN	TOTAL	36.17	11.86	46
	BOYS	43.15	9.90	27
	GIRLS	26.26	5.76	19
1ST GRADE	TOTAL	49.56	21.12	59
	BOYS	67.69	14.18	29
	GIRLS	32.03	7.21	30
2ND GRADE	TOTAL	56.49	24.72	47
	BOYS	82.68	14.43	19
	GIRLS	38.71	9.60	28
3RD GRADE	TOTAL	73.73	24.98	48
	BOYS	97.14	16.77	22
	GIRLS	53.92	11.92	26
4TH GRADE	TOTAL	75.48	25.49	48
	BOYS	97.00	16.57	22
	GIRLS	57.57	12.03	26
5TH GRADE	TOTAL	83.35	27.16	55
	BOYS	102.22	16.46	32
	GIRLS	57.09	13.78	23
ALL GRADES	TOTAL	62.67	28.28	303
	BOYS	81.07	26.13	151
	GIRLS	44.39	15.86	152

increased from kindergarten through the third grade, plateaued at grade 4, and increased again in grade 5. The mean performance of the girls increased across grades until they experienced a plateau between grades 4 and 5. At all grade levels, the boys threw the ball substantially farther than the girls.

The average stage exhibited by the children also increased across grade levels (Table 5). However, because of the high percentage of boys

Table 5

Means and Standard Deviations for Throwing Stage (range = 1 to 5)

Grade	Total/ Gender	Means	Standard Deviation	Cases
KINDERGARTEN	TOTAL	3.48	1.44	46
	BOYS	4.11	1.28	27
	GIRLS	2.58	1.17	19
1ST GRADE	TOTAL	4.07	1.28	59
	BOYS	4.90	.31	29
	GIRLS	3.27	1.36	30
2ND GRADE	TOTAL	4.13	1.17	47
	BOYS	4.89	.32	19
	GIRLS	3.61	1.26	28
3RD GRADE	TOTAL	4.54	.74	48
	BOYS	4.82	.66	22
	GIRLS	4.31	.74	26
4TH GRADE	TOTAL	4.71	.63	48
	BOYS	5.00	.00	22
	GIRLS	4.46	.86	26
5TH GRADE	TOTAL	4.84	.37	55
	BOYS	5.00	.00	32
	GIRLS	4.61	.50	23
ALL GRADES	TOTAL	4.30	1.11	303
	BOYS	4.78	.69	151
	GIRLS	3.83	1.23	152

using the mature stage level (stage 5), the increase was due primarily to the improvement in throwing form by the girls. The mean stage for girls increased each year from 2.58 (5 maximum) in kindergarten to 4.61 in grade 5. In contrast, the mean stage for kindergarten boys already was 4.11. The first, second, and third grade boys leveled off with means of 4.90, 4.89, and 4.82, respectively. All the boys tested in grades 4 and 5 used the mature pattern.

The means for height and weight systematically increased across the grade levels. Boys were taller than the girls at all grade levels except grade 4 where the mean height was approximately even. The boys also were heavier than the girls except at grades 3 and 4 where the girls were approximately 4 and 6 pounds heavier, respectively, than the boys. (See Tables B-1 and B-2).

Both boys and girls increased their grip strength from kindergarten through grade 5. The boys were stronger than girls at all grade levels. The range of the difference between boys and girls increased from 1.62 kg in kindergarten to 5.63 kg in grade 5. The pattern for push-ups was different. Mean performance improved from kindergarten until grade 4 and then decreased. Peak performance for the boys occurred in grade 3 and for the girls in grade 4. Boys did more push-ups than girls at all grade levels. (see Tables B-3 and B-4)

A test, retest correlation analysis was performed on the strength measures. The retests were completed four weeks after the original strength measures were obtained. Throwing hand grip strength was retested on the students in kindergarten, second grade, and fourth grade. The first graders, third graders, and fifth graders were retested on their push-ups. The results (Table 6) showed a significant

Table 6

Test, Retest Correlation Coefficients of Strength Measures in Selected Grades

Grip Strength		Push-ups	
Grade	R	Grade	R
K	.880*	1	.664*
2	.939*	3	.902*
4	.907*	5	.852*

* $p < .01$ (2 - tailed)

correlation ($p < .01$) for every group tested. The first graders retested on push-ups had the lowest correlation coefficient of any group ($r = .66$). This lower correlation emphasizes the need for careful control of the push-ups test for younger children. The remaining coefficients ranged from .852 to .939. Thus the performance of the children on the strength tests were judged to be consistent and acceptable.

Predictability of Throwing for Distance

A selected number of growth, strength, and performance variables were examined for their ability to account for the variability in a throw for distance. A determination of the relationship among these variables was important for predicting a distance throw and to provide covariates in the analysis of the variance of throwing for distance. The predictability of throwing for distance was studied in three groups: girls, boys, and all subjects combined so that the correct

variables could be controlled according to the subject group being analyzed.

Three intercorrelation matrices were obtained, one for all the subjects and one for each of the gender groups. The correlation coefficients of the variables are listed in Tables 7, 8, and 9. The intercorrelation matrix for all subjects (Table 7) shows a correlation coefficient of .588 between throwing style and throwing distance. Although modest in magnitude, it is comparable to the relationship of age ($r = .586$), grade ($r = .570$), and height ($r = .592$) to throwing distance. Its relationship to throwing distance is greater than that of weight ($r = .440$), grip strength ($r = .428$), or push-ups ($r = .214$) to throwing distance. A comparison of the boys' matrix with the girls' matrix (Tables 8 and 9) reveals similar coefficients for most of the variables. The major exception to the general trend is stage, whose correlations with the other variables are noticeably higher for the girls than for the boys. For example, the correlation between stage and the distance throw was .42 for the boys and .61 for the girls. The higher correlations are a result of the greater variability of stage for the girls when compared to the boys. The percentage of boys using a stage 5 throwing pattern was so large (88%) that there was very little variability of stage for the boys. The small variability of stage and the greater variance of throwing distance resulted in a smaller correlation value for the boys.

Three stepwise regression analyses were run to determine which of the variables of height, weight, push-ups, and grip strength studied would be important for predicting throwing distance and for use as covariates in further analyses. To qualify as a covariate the variable

Table 7

Intercorrelation Matrix for Boys and Girls Combined

	Age	Grade	Height	Weight	Stage	Distance Throw	Grip Strength	Push- ups
Age		.976	.879	.737	.425	.586	.790	.144
Grade	.976		.867	.729	.396	.570	.773	.135
Height	.879	.867		.832	.391	.592	.825	.022
Weight	.737	.729	.832		.288	.440	.796	-.067
Stage	.425	.396	.391	.288		.588	.428	.214
Distance Throw	.586	.570	.592	.440	.588		.675	.307
Grip Strength	.790	.773	.825	.796	.428	.675		.182
Push-ups	.144	.135	.022	-.067	.214	.307	.182	

Table 8

Intercorrelation Matrix for the Boys

	Age	Grade	Height	Weight	Stage	Distance Throw	Grip Strength	Push- ups
Age		.978	.894	.758	.334	.769	.848	.161
Grade	.978		.876	.749	.341	.779	.836	.168
Height	.894	.876		.842	.283	.719	.871	.019
Weight	.758	.749	.842		.196	.541	.860	-.081
Stage	.334	.341	.283	.196		.415	.262	.064
Distance Throw	.769	.779	.719	.541	.415		.662	.267
Grip Strength	.848	.836	.871	.860	.262	.662		.115
Push-ups	.161	.168	.019	-.081	.064	.267	.115	

Table 9

Intercorrelation Matrix for the Girls

	Age	Grade	Height	Weight	Stage	Distance Throw	Grip Strength	Push- ups
Age		.974	.864	.715	.573	.727	.783	.112
Grade	.974		.865	.711	.538	.729	.784	.094
Height	.864	.865		.823	.488	.688	.798	-.020
Weight	.715	.711	.823		.360	.542	.777	-.082
Stage	.573	.538	.488	.360		.607	.461	.234
Distance Throw	.727	.729	.688	.542	.607		.663	.198
Grip Strength	.783	.784	.798	.777	.461	.663		.161
Push-ups	.112	.094	-.020	-.082	.234	.198	.161	

must enter the regression equation and contribute an increase of at least .05 to the adjusted R^2 . The value of a .05 increase in the adjusted variance was used to eliminate variables that did not contribute a substantial gain in throwing distance. One regression was run for all the subjects, one for the boys, and one for the girls.

The variables that entered the regression equation for boys and girls combined were grip strength, push-ups, height, and weight (Table 10). However, of these four variables, only grip strength added a minimum of .05 to the adjusted R^2 . Grip strength had the highest individual correlation with distance throw with an $R = .675$ and an adjusted R^2 of .454. In the analyses involving the performance of boys and girls combined, grip strength was the only variable used as a covariate.

In the regression equation for the boys the variables that entered were height and push-ups (Table 11). Both variables added at least .05

Table 10

Stepwise Multiple Regression of Predictor Variables on Throwing Distance for Boys and Girls Combined

Variable	Multiple R	R^2	Adjusted R^2	SEE	F Ratio	Regression Coefficient
Grip Strength	.675	.456	.454		7.696	3.26
Push-ups	.701	.492	.488		3.786	.65
Height	.709	.503	.498		4.465	2.28
Weight	.730	.533	.526	19.46	-4.341	-.50
Constant					-4.129	-85.07

to the adjusted R^2 , so height and push-ups were used as covariates in analyses of the boys. Height alone accounted for an $R = .719$ and for an adjusted R^2 of .514. Height and push-ups combined for a multiple R of .763 and an adjusted R^2 of .576.

The regression equation for girls entered height first, push-ups second, and grip strength third. However, neither push-ups nor grip strength raised the adjusted R^2 the required .05. Therefore height was

Table 11

Stepwise Multiple Regression of Predictor Variables on Throwing Distance for Boys

Variable	Multiple R	R^2	Adjusted R^2	SEE	F Ratio	Regression Coefficient
Height	.719	.518	.514		13.443	3.90
Push-ups	.763	.582	.576	16.95	4.767	.84
Constant					-8.751	-137.89

Table 12

Stepwise Multiple Regression of Predictor Variables on Throwing Distance for Girls

Variable	Multiple R	R^2	Adjusted R^2	SEE	F Ratio	Regression Coefficient
Height	.688	.474	.471		5.318	1.90
Push-ups	.720	.519	.512		2.927	.45
Grip Strength	.732	.536	.527	10.92	2.355	.83
Constant					-4.774	-72.75

the only variable used as a covariate for the girls accounting for an R of .688 and an adjusted R^2 of .471.

Differences in Throwing Distance for Gender and Grade

A grade by gender (6 X 2) ANCOVA was used to evaluate the first two hypotheses: 1) for each grade level, boys will throw a ball farther than girls and 2) boys or girls in a higher grade will be able to throw a ball farther than their gender counterparts in a lower grade. The ANCOVA showed significant gender $F(1,302) = 641.36$, $p < .001$ and grade $F(5,298) = 103.53$, $p < .001$ main effects in the distance students can throw the ball. The two-way interaction between gender and grade also was found to be significant $F(5,298) = 9.55$, $p < .001$. The finding that the boys threw significantly farther than the girls was expected and agrees with the numerous studies examined by Nelson and French (1985).

Because the two-way interaction between gender and grade was significant, the gender groups had to be examined simultaneously. A Tukey multiple comparison test was run to determine which grades were significantly different from each other. The means and standard deviations for each grade are displayed in Table 4. The significant differences ($p < .05$) between grades is shown in Table 13.

The mean distance subjects threw the ball increased each grade from kindergarten through fifth grade. The mean distance throws of kindergarten, first, and second graders were significantly different from each other and from grades 3, 4, and 5. However, there was no significant difference in mean throwing distance between grades 3, 4, and 5. Even though no significant differences existed between the third, fourth, and fifth grades, the trend of an increase in throwing

Table 13

Significant Differences of Throwing Distance Between Grades K and 5

		Grade					
Grade		K	1	2	3	4	5
K		---					
1		*	---				
2		*	*	---			
3		*	*	*	---		
4		*	*	*	ns	---	
5		*	*	*	ns	ns	---

* - Significance at the $p < .05$ level

performance in succeeding grades reported in previous studies (Hanson, 1965; Keogh, 1965) was confirmed in the present study.

To examine the significant effect of the interaction between gender and grade, two graphs (Figures 1 and 2) were plotted. Figure 1 shows the mean throwing distances of boys and girls for each grade. Figure 2 examines the gain each gender group made between each of the successive grades studied. In looking at Figures 1 and 2, there are two distinct sections. The first section is between kindergarten and third grade where both genders are increasing their throwing distances every year. The second section is between grades three and five where a leveling off of throwing distance occurs. The increase between the last two years is smaller than the smallest increase of any of the previous years. In fact, the gain from third grade to fifth grade for the boys is approximately one third of the smallest gain of any year between

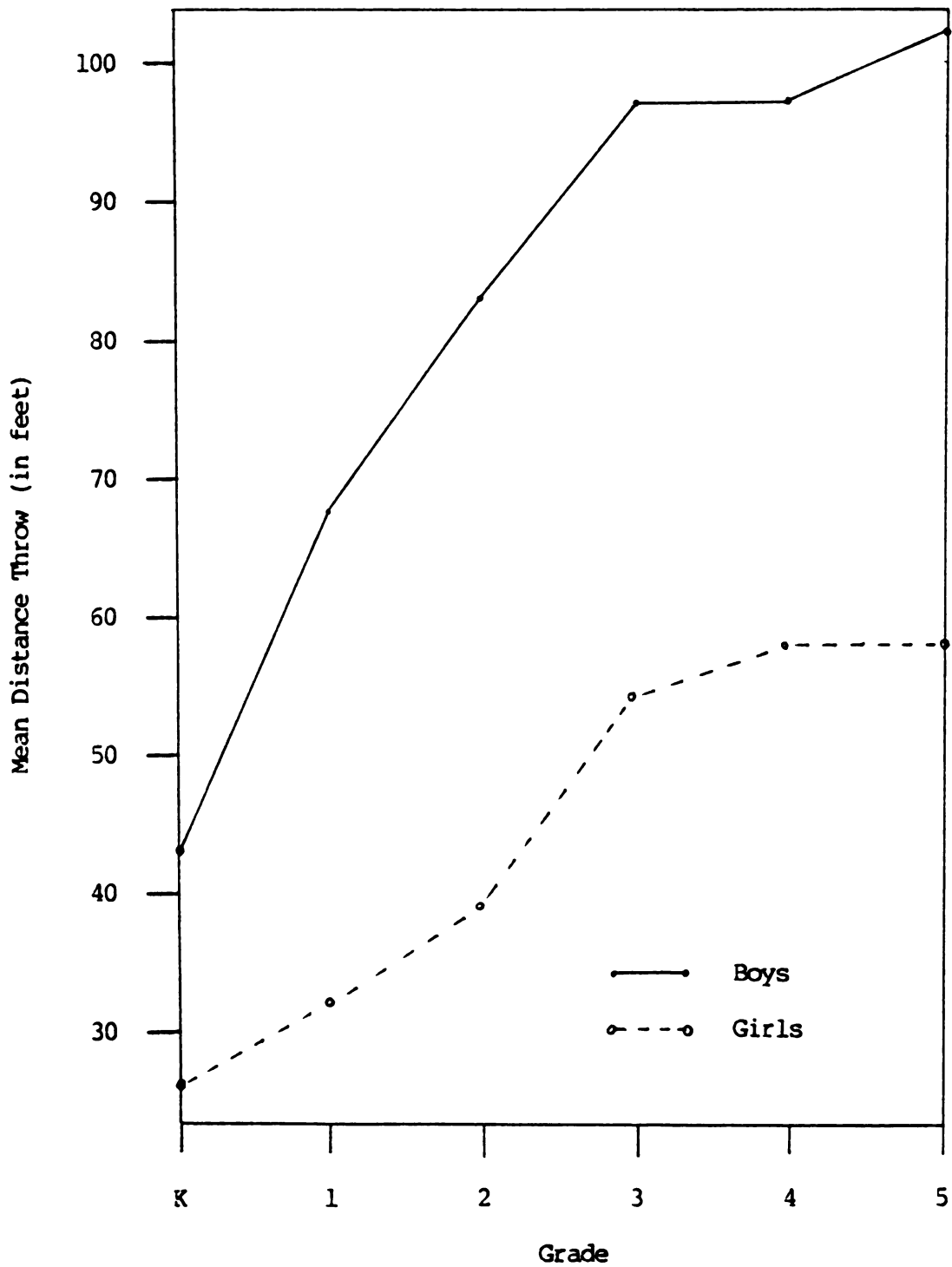


Figure 1. Mean distance throw of girls and boys in Kindergarten through 5th Grade.

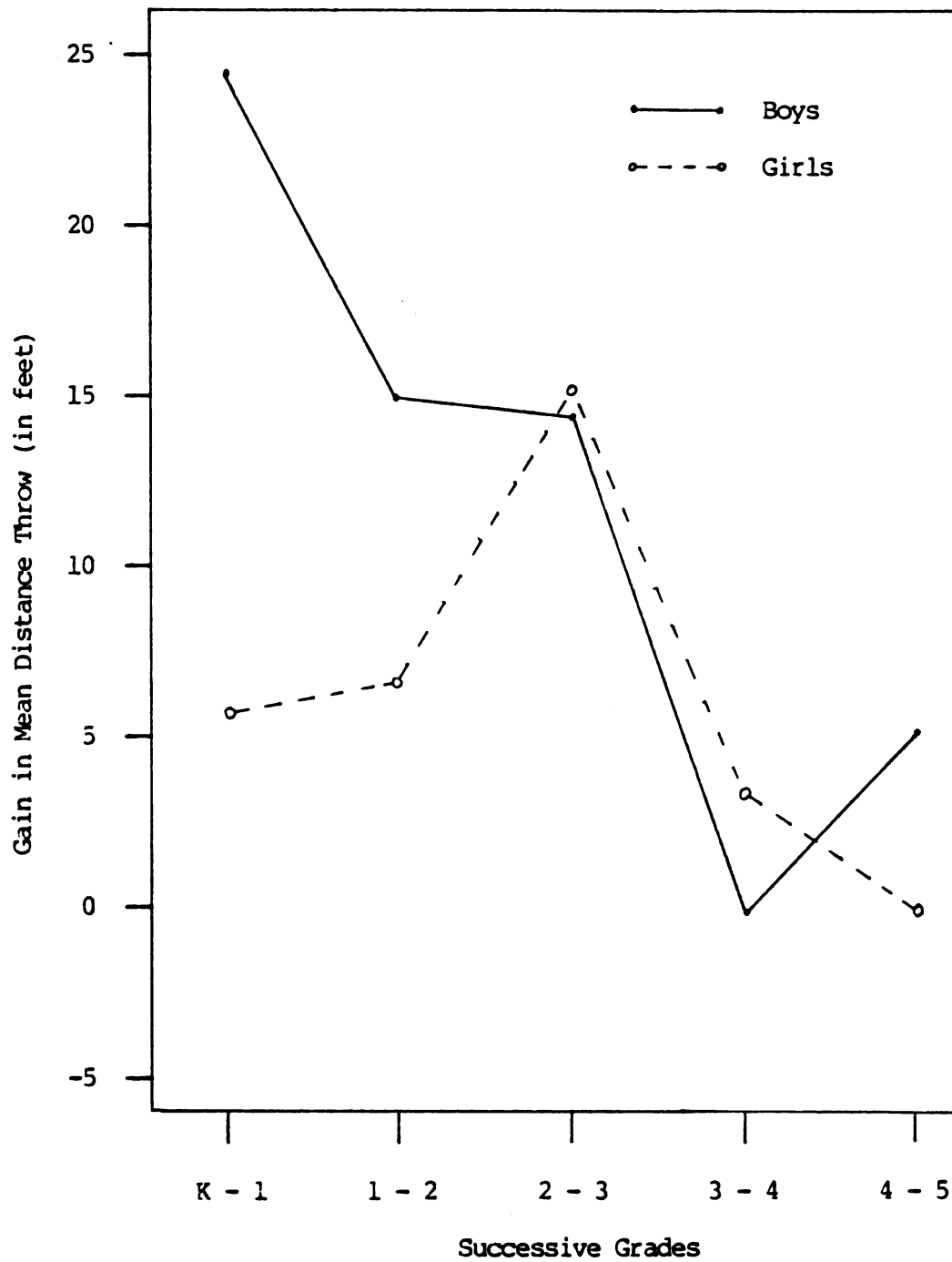


Figure 2. Gain in mean distance throw of girls and boys between successive grades.

kindergarten and third grade. For the girls, the gain from third grade to fifth grade is approximately one half of any of the previous years.

Even though both gender groups exhibited improvement from grades kindergarten through third grade and a leveling off between third and fifth grades, there was a difference within each section between the boys and girls. In the section which includes kindergarten through the third grade, the boys increased the most between kindergarten and first grade (24.5 feet) and had steady improvement from first grade to second grade (15.0 feet) and from second grade to third grade (14.5 feet). The girls showed the steady improvement in the first two years with an improvements of 5.8 feet from kindergarten to first grade and 6.7 feet from first grade to second grade. Then the girls experienced their biggest increase in throwing distance between second grade and third grade with an increase of 15.2 feet—more than twice the increase in any other year. So the gender trends for throwing distance in kindergarten through the third grade was for the boys to increase the most between kindergarten and first grade and the girls to increase the most between second and third grades.

The boys and girls also differed in their increases in the fourth and fifth grades. The boys did not increase their throwing distance from the third to the fourth grade while they did increase 5.0 feet between the fourth and fifth grades. The girls, on the other hand, increased the distance they threw the ball 3.3 feet between the third and fourth grades but did not increase their distance between the fourth and fifth grades. The differences between the boys and girls resulted in a significant interaction between gender and grade.

Differences in the Effect of Stage on Throwing Distance

The third hypothesis, that subjects of the same gender in the same grade who have a more mature form of throwing (as determined by the MSU developmental sequence) will throw a ball farther than boys or girls who exhibit a less mature stage of throwing, was examined separately for boys and girls.

Boys

Because of the large percentage of boys using the stage 5 throwing pattern, the anticipated 6 X 5 grade by stage ANCOVA could not be run. In checking the crosstabs table (Table 14), the only grade that had two or more throwers in stages 1, 2, or 3 was kindergarten, so it was the only grade that could be examined for the effect of stage on throwing distance. It was also noted that stages 1, 2, and 3 in kindergarten only had two subjects in each cell, which were not enough to run analyses. Because the first three stages represent an immature throwing pattern, these cells were collapsed into one ($n = 6$). An ANCOVA was then run on the kindergarten boys comparing throwing distance by stage using push-ups and height as covariates. The main effect of stage was not significant, $F(2,25) = 1.71$, $p = .205$, in determining throwing distance for kindergarten boys. The covariates of push-ups, $F(1,26) = .25$, $p = .635$, and height, $F(1,26) = .01$, $p = .933$, also were shown to be non-significant.

Even though stage was not shown to be a significant indicator of throwing ability, the general trend of the boys showed an improvement from stages 1, 2, and 3 combined ($n = 6$; $M = 36.8$), stage 4 ($n = 6$, $M = 42.7$), and stage 5 ($n = 15$; $M = 45.9$). Leme (1973) noticed that some women who moved from a lower stage of throwing to a higher one lost

Table 14

The Number of Boys at Each Stage of Throwing in Each Grade.

Stage	Grade					
	K	1	2	3	4	5
5	15	26	17	20	22	32
4	6	3	2	1		
3	2					
2	2			1		
1	2					

distance in their performance throw. It has been postulated that performance may decrease during the transitional time when a person is changing from one stage to another because time is needed to coordinate the new movements in the pattern and make it more efficient.

Throwing performance, may be greater when using a relatively stable less mature stage to its full potential than when an individual is in transition to a more mature stage. The kindergarten boys are all in the process of forming their motor patterns and constantly refining them. Stage 1 provides the thrower with a stable base to generate force to the ball. With each succeeding stage, the base is less stable and either more body parts are moving or the body parts are moving through a greater range of motion. In young throwers, such as kindergarten boys, the transition from one stage to another calls for continuous learning to control the new movements and at any given time there will exist a wide range of efficiency in throwing performance at a particular stage level. Stage 1 provides the kindergarten thrower with the stable base

to involve the basic arm movements to perform a fairly good throw. Kindergarten boys using the fourth and fifth stage of throwing have been able to increase their throwing distance but they have not yet been able to fine tune the acceleration and deceleration of body parts to take full advantage of the improved stage of throwing. Thus the kindergarten boys have shown an increase in throwing distance for the different stages but the distances have not been found to be significantly different.

Girls

In investigating the effect of throwing stage on throwing distance for the girls, the anticipated 6 X 5 grade by stage ANCOVA could not be run because several open cells were noted (Table 15). Kindergarten was dropped from the initial analysis because there were no stage 5 girls. Fifth grade was also dropped because all the girls were throwing with a stage 4 or 5 pattern. Stages 1 and 2 were dropped because of empty cells and insufficient numbers in others. The largest section of grade by stage without any open cells was grades 1 through 4 and stages 3 through 5. An ANCOVA was run using grade (1,4) and stage (3,5) with height as a covariate. In a second analysis a one way ANCOVA was run on the fifth grade girls to determine if there was a significant difference between stage 4 and 5 throwers. Height was also used as covariate in the second ANCOVA. Finally, a one way ANCOVA of throwing distance by stage with height as the covariate was run for all the girls.

Three general trends about stage and throwing distance can be observed when examining the means of throwing distance for girls by stage and grade listed in Table 16. First, the higher grades (3 and 4) have the largest percentage of throwers using the most skilled stage.

Table 15

The Number of Girls at Each Stage of Throwing in Each Grade.

Stage	Grade					
	K	1	2	3	4	5
5		4	6	12	17	14
4	5	14	13	10	5	9
3	6	4	5	4	3	
2	3	2			1	
1	5	6	4			

Table 16

Means of the Distance Throw by Grade and Stage for Girls

Stage	Grade				Row Totals
	1	2	3	4	
5	34.8 (n=4)	44.3 (n=6)	59.2 (n=12)	61.7 (n=17)	55.5 (n=39)
4	35.2 (n=14)	39.8 (n=13)	48.2 (n=10)	51.2 (n=5)	41.6 (n=42)
3	29.5 (n=4)	31.8 (n=5)	52.5 (n=4)	42.3 (n=3)	38.4 (n=16)
Column Totals	34.1 (n=22)	39.3 (n=24)	53.9 (n=26)	57.3 (n=25)	46.7 (n=97)

(Notice the larger number of stage 5 throwers when the higher grades are compared with the lower grades.) The second trend is that for each grade the students using a more mature stage throw the ball farther. The two exceptions to this trend are the first grade stage 5 throwers who did not throw as far as the first grade stage 4 throwers, and the third grade stage 3 throwers who threw farther than the stage 4 throwers. The third trend is that for each stage, girls in the higher grades threw the ball farther than girls in the lower grades. Once again the stage 3 throwers in the third grade were the exception. They threw the ball farther than the fourth grade stage 3 and stage 4 throwers.

The trends in the throwing distance of the girls in grades 1 through 4 using stages 3, 4, and 5 were examined in the first ANCOVA. Height was used as a covariate. The main effects for stage, $F(2,94) = 9.04$, $p < .001$, and grade, $F(3,93) = 6.26$, $p = .001$, were significant. The covariate, height, $F(1,95) = 69.10$, $p < .001$, also was significant. The two-way interaction between stage and grade, $F(6,90) = 1.13$, $p = .353$, was not significant. Thus both stage and grade were shown to have significant effects on the distance a ball could be thrown by first, second, third, and fourth grade girls.

The Scheffe multiple comparison test was used to compare the different levels of grade and stage. The results of the significant differences between the grades and stages in throwing distance are given in Tables 17 and 18, respectively. In reviewing the differences between the grades, there was a significant increase in the throwing distance between second and third grade. Thus, the mean throwing performance for grades 1 and 2 was significantly different from that of grades 3 and 4. However, the increases between first and second grade and between third

Table 17

Significant Differences of Throwing Distance for Grades 1 to 4

Mean	Grade	Grade			
		1	2	3	4
34.1	1	---			
39.3	2	ns	---		
53.9	3	*	*	---	
57.3	4	*	*	ns	---

* - Significance at the $p < .05$ level

Table 18

Significant Differences of Throwing Distance for Stages 3 to 5

Mean	Stage	Stage		
		3	4	5
38.4	3	---		
41.6	4	ns	---	
55.5	5	*	*	---

* - Significance at the $p < .05$ level

and fourth grade were not significant. In contrasting the different stages, mean throwing distance for stage 3 was not significantly different from that of stage 4 but it was significantly different from that of stage 5. Also, the mean throwing distance performance for stages 4 and 5 were significantly different.

The second ANCOVA for the girls examined those in fifth grade, which had only stage 4 and 5 throwers. In comparing the two stages a difference approaching significance was found for the main effect of stage $F(1,22) = 4.21$, $p = .054$. A nonsignificant difference was obtained for the covariate of height $F(1,22) = 1.17$, $p = .293$. These results, in general, support the hypothesis that a more mature stage will result in a longer distance throw.

The results of this ANCOVA provide more evidence of the difference in throwing distance between girls using the stage 5 throwing motion and those using stage 4. These results are in agreement with the findings of the ANCOVA for the first through fourth grade girls which also found a significant difference in throwing for distance between stage 5 and stage 4 throwers. The general trend shows that as the girls get older more of them throw at the mature stage 5, and therefore can throw a ball farther. Of the fifth grade girls in this study, 60 per cent throw using the stage 5 pattern. The trend would seem to indicate that a number of girls would have been using the stage 5 pattern for a period of time and thus should have been able to improve their efficiency in the use of this pattern. If there is a difference between a stage 5 thrower and a stage 4 thrower, they should have been able to demonstrate it. The ANCOVA results verify that this is the case.

The final comparison for the girls examined their throwing distance by stage. The cell for stage two girls had an n of 6 which was considered small especially compared to the 56 girls in stage 4 and 53 girls in stage 5. A comparison was made of the stage 2 throwers with matched pairs of stage 1 and stage 3 throwers. The stage 2 subjects were matched by grade, height, weight and strength in that order. The matched pairs of stage 1 and 3 throwers were combined with the stage 2 throwers and were placed in a one way ANOVA of throwing distance by stage. The ANOVA showed no significant difference between the stages $F(2,15) = .27, p = .767$. Since the ANOVA did not produce a significant difference between stages, stages 1, 2, and 3 were collapsed into one stage for comparison in the ANCOVA.

The one way ANCOVA with stage as the main effect and height as the covariate found the main effect of stage $F(2,149) = 22.33, p < .001$ to be significant. The covariate of height $F(1,150) = 46.35, p < .001$ was also found to be significant. The Scheffe multiple comparison test showed that all three stages—1, 2, and 3, combined; stage 4; and stage 5 were significantly differently from each other.

The third ANCOVA, used to evaluate the effect of the stage pattern on the girls' throwing distance, also supports the hypothesis that a more mature stage will increase throwing distance. It is not surprising that the covariate, height, was found to be significant because of the large difference of height between kindergarten and fifth grade girls, and the trends previously stated about the increase in distance throws with increased age. It is important to note that for the entire age group and taking the covariate of height into account, the stage pattern

of the thrower still had a significant influence on the distance the girls could throw the ball.

Although it cannot be stated that every girl who uses a more mature throwing pattern, as determined by her throwing stage, will throw farther than one who uses a less mature stage, certainly evidence is provided in this study to support the hypothesis that the stage of throwing individuals use has an important influence on the distance they can throw a ball.

This study provides support for the use of the Michigan State University developmental sequence of throwing in assessing throwing performance. The study has shown differences in throwing distance between girls using a more mature throwing pattern and girls using a more rudimentary throwing stage. However, the stage sequence is not a panacea, explaining all there is to the throwing behavior. It must be remembered that throwing is a complex motion requiring precise coordination of many body parts. The stage sequence explains the major movements that the body must make to produce a better throw, but it cannot explain every minute detail of the throw. As it was previously noted, there are a number of other factors that affect throwing performance such as strength and body size. Because of its complexity, throwing performance cannot be easily explained and compartmentalized. The MSU stages of throwing do provide a way to explain some of the differences in throwers and thereby provide a sequential progression to follow in helping students develop the proper throwing patterns of a mature throw. Within these limits it can be a valuable tool for the teacher/coach.

This study does point to some limitations of the stage theory. In this study, the boys had already reached the mature stage by the first grade. If the students have already reached stage 5, the stage theory cannot provide any additional information regarding the differences between the throwing distance of the boys in the first through fifth grades. It is noted that there still exists a great difference in the throwing distance of the boys even though they are in the same grade and use the same throwing form. There must be a refining of the stage 5 pattern in the timing and sequencing of the motion, along with physical and maturation factors such as height and strength, that goes beyond the easy categorizing of the motion into stages, and this refining adds to length of the throw.

This study provides information, within the limits of the stage sequence that students (particularly girls) who use a more mature form of throwing do indeed experience an increase in throwing distance. This study provides evidence that the stage sequence for throwing does provide important information to the teacher/coach by providing important clues which can lead the performer to a more efficient throw.

CHAPTER 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to evaluate the relationship between the qualitative throwing motion used by children and the distance they could throw a ball. The study also examined the influence of grade, gender, grip strength, push-ups, height, and weight on throwing distance.

The subjects were 303 students in a private Christian elementary school in kindergarten through fifth grade. There were 151 boys and 152 girls participating in the study. The students came from predominantly white, middle class, Protestant families residing in a small Midwest community. All the students in kindergarten through the fifth grade were encouraged to participate, but a signed consent form from a parent and from the students themselves were required to participate.

The students watched a videotape showing a 6th grade model of their gender performing all the tasks they were required to do during the testing. The students then signed a consent form if they wished to participate. They proceeded to a warm-up area where they made 10-15 throws with a rag baseball similar to the one used for the distance throw. Next, they went to the station where they threw the rag baseball for distance. They were reminded again that the throw was going to be measured by the distance the ball traveled in the air. All the subjects made three throws, with the longest throw being used in the study as the subject's score. The subjects were videotaped at the time of their

distance throws and the videotape was reviewed at a later date to determine the stage they were using to throw the ball. The subjects then went inside the school to have their throwing hand grip strength and push-ups performance assessed. Push-up performance was videotaped and the videotape was reviewed at a later time to verify the correct number of push-ups for each subject. The subjects' height and weight were obtained within two weeks of the other tests. Grade, gender, and age in months also were noted for each subject.

Correlation coefficients were obtained between each of the variables. In the analysis involving all the subjects, grip strength had the highest correlation coefficient with throwing distance at .675. Stage also had a moderate correlation with throwing distance at .588.

The major hypothesis was that the higher the stage of throwing used, the longer the distance throw. The range of stages exhibited by the boys was very limited with only the kindergarten boys having stage 1, 2, and 3 throwers. Thus, the only comparison that could be made between throwing stage and throwing distance was with the kindergarten boys. The resulting ANCOVA showed that there were no significant differences in throwing distance among the throwing stages for the kindergarten boys.

The range of stages was greater for the girls, although very few girls threw using stage 1 or 2 patterns. In comparing the girls in grades 1 through 4 who used the stages 3 through 5, stage 5 was significantly different from stages 3 and 4, but stage 3 and 4 were not significantly different from each other. The fifth grade girls used only stage 4 and stage 5 throwing patterns. When their performance was

analyzed, a significant difference in throwing distance was found between stage 4 and stage 5 throwers. Finally, the throwing distance of all the girls was compared with stages 1, 2, and 3 combined into an immature pattern group. The results showed that there was a significant difference between stages 5, 4, and the immature stages in throwing distance.

Summary of Results

The purpose of this study was to investigate 1) the difference between girls and boys in the performance of a distance throw; 2) the relationship of grade level to the distance throw; and 3) the relationship of developmental throwing stage to the distance a ball can be thrown. The following results were obtained:

1. ANOVA procedures, yielded significant gender and grade effects. A significant grade by gender interaction also was found. Boys threw the ball significantly farther than the girls.
2. Children in kindergarten, first, and second grade were significantly different from each other and from children in grades 3, 4, and 5 in how far they could throw a ball.
3. There was no significant difference in mean throwing distance between third, fourth, and fifth graders.
4. The range of stages for the boys was so limited that the effect of throwing stage on the distance throw could only be analyzed at the kindergarten level.
5. Comparison of kindergarten boys' distance throws with their throwing stage showed an improvement in mean scores from stage to stage (collapsing stages 1, 2, and 3). When adjusted for the

- covariates of push-ups and height, however, the mean scores for throwing distance by stage were not significantly different.
6. For girls in grades 1 through 4, throwing distance for first and second graders was significantly different from that of the third and fourth graders. However, the mean throwing distance of first graders was not significantly different from that of the second graders, and the mean throwing performance of the third graders was not significantly different from that of the fourth graders.
 7. For girls in grades 1 through 4, girls with a stage 5 throwing pattern could throw a ball significantly farther than girls with a stage 3 or stage 4 pattern, but the means for throwing distance of the stage 3 and stage 4 throwers were not significantly different.
 8. In comparing fifth grade girls, stage 5 throwers could throw a ball significantly farther than stage 4 throwers. The covariate height, however, was not significant.
 9. When examining all the girls by stage, and collapsing stages 1, 2, and 3 into a new stage "3", a significant difference was found between the new stage "3", stage 4, and stage 5 throwers. The covariate of height also was significant.
 10. The covariates were significant factors in the throwing performance of children when the ANCOVA was used to compare students of more than one grade. When ANCOVA involved students within one grade (kindergarten boys—push-ups and height, and fifth grade girls—height) the covariates were not significant.

11. Of the variables studied, push-ups had the lowest correlation coefficient with throwing distance ($r = .307$, boys and girls combined; $.262$, boys; $.198$ girls).

Conclusions

The results suggest the following conclusions in reference to the hypotheses proposed:

1. The hypothesis that boys would throw a ball farther than girls in their own grade was supported. For grades kindergarten through fifth grade, the boys threw a ball significantly farther than the girls. Even though the analyses used the covariate of grip strength to factor in some of the physical differences between boys and girls, the boys still threw significantly farther than the girls.
2. The second hypothesis proposed that members of the same gender in a higher grade will throw a ball farther than those in a lower grade. This hypothesis was partially supported. The mean distance throw increased for each of the grades with two exceptions—the third and fourth grade boys were approximately equal as were the fourth and fifth grade girls. Kindergarten, first, and second grades were significantly different from each other and from each of the other grades, but the third, fourth, and fifth grades were not significantly different from each other. For the girls, the only successive grades that were significantly different were second and third grade. For the boys, kindergarten and first grades were significantly different from all the other grades, but not from each other. The only other grades that were significantly different from each other

were the second and fifth grades. Again there was no significant difference between the third, fourth, and fifth grades. Under the conditions of this study, the lower grades (kindergarten through second grade) supported the hypothesis of the higher grades throwing farther but the third, fourth, and fifth grades did not.

3. The third hypothesis stated that children of the same grade and gender who have a more mature stage of throwing will throw a ball farther than children who use a less mature stage of throwing. The ANCOVAs using height as a covariate showed that stage 5 girls threw the ball significantly farther than stage 4 girls in grades 1 through 5. There was an improvement in the mean throwing distances of stage 4 throwers in comparison with stage 3 throwers, but the differences were not significant in the grades one through four. There were not enough stage 1 or stage 2 throwers to make any comparisons. When comparing all of the girls, a category of immature throwers was formed which included stage 1, 2, and 3 throwers. In the ANCOVA comparing the immature stage category with stage 4 and stage 5, a significant difference was found between all three groups of throwers.

The kindergarten boys showed an increase in mean throwing distance between the immature group, stage 4, and stage 5 throwers but none of the three groups were significantly different from each other. Ninety-four percent of the boys in grades one through five used the mature throwing pattern (stage 5). The large percentage of boys exhibiting the stage 5

throwing pattern precluded analyses using developmental throwing stage as a main effect.

The narrow range of throwing stages used by the boys prevented testing the hypothesis that a more mature stage of throwing produces a farther distance throw. However, the differences in throwing distance demonstrated by the girls who used the different stages of throwing pattern lend strong support to this hypothesis and suggest that the method of throwing a ball is important to the distance a person achieves with one's throw.

Recommendations

As a result of this study, the following recommendations are made:

1. This study should be replicated using younger boys to provide the full array of stages for analysis of throwing behavior.
2. A longitudinal study with girls should be conducted, working on their form to determine if an increase in their stage of throwing increases their throwing distance.
3. A larger sample of throwers needs to be tested to see if the percentages reported by Way et al. (1979) for each stage of throwing need to be revised.
4. Highly motivated girls need to be challenged in their throwing ability at a young age to see if they achieve the same performance results as boys.

APPENDICES

APPENDIX A

**Parental Information Sheet and
Parental and Student Consent Forms**

Parental Information Sheet:

Dear Parent,

I am planning to assess the throwing ability of students in our elementary school in fulfillment of my master's thesis at Michigan State University. I am determining the relationship between the quality of the throwing motion and the distance the ball is thrown. I am also examining the effect strength, height and weight play in the process. I hope this study will provide a better understanding of how to plan, implement and evaluate effective physical education instruction as it relates to throwing.

If you allow your child to participate in this study, he/she will be evaluated according to his/her height, weight, strength, the distance he/she can throw a ball, and the form he/she uses in throwing the ball.

If you allow your child to participate in this study, he/she will be videotaped as he/she performs a maximal throw for distance. Videotaping will permit me to evaluate your child's throw according to the developmental stages of throwing formulated by researchers at Michigan State University. Strength will be measured by the number of push-ups that he/she can do in 30 seconds and by a hand dynamometer test. In the hand dynamometer test your child will squeeze a hand dynamometer as hard as he/she can. The dynamometer will register a reading corresponding to how hard he/she squeezed it.

For this study, your child will be given an identification number to protect his/her anonymity. We will use this identification number rather than the child's name when reporting the results of this study.

These tests will be administered in the school's gymnasium or on the athletic field by the physical education instructor and study author, Randy Baker. Your child will be told the purpose of the study and will be given test instructions. Students will be informed that they may choose not to participate in these tests.

I believe that this study will have substantial benefits in learning more about the fundamental motor skill of throwing. By learning more about the different factors that effect motor skills teachers can be helped to improve physical education and sports programs. Please help to achieve this goal by permitting your child to participate in this study. Thank you.

The testing date for your child's class, _____, is _____.
If you have any questions, please feel free to call me either at school or at home.

Sincerely,

Randall L. Baker

Parental Consent Form:

Motor Development Thesis Study

Consent Form

The purpose and extent of involvement in this project have been explained to my satisfaction. I agree to my child(ren)'s participation in this project. I understand the risks involved and am free to discontinue participation at any time without recrimination.

I understand that if my child is injured as a result of my child's participation in this research project, emergency medical care will be provided if necessary, but these and any other medical expenses must be paid from my own health insurance program.

I understand the results of my child(ren)'s participation will be treated with strict confidence. I also understand that I must give my written permission before such films may be used for educational or other purposes.

Child(ren)'s Name: _____

Parent's Signature: _____

Date: _____

Student Consent Form:

I have seen the videotape explaining what I am going to do in the throwing study and I am willing to participate in this study.

APPENDIX B

Means and Standard Deviations of
All Variables
By Grade and Gender

Table B - 3

Means and Standard Deviations for Grip Strength (in Kg)

Grade	Total/ Gender	Means	Standard Deviation	Cases
KINDERGARTEN	TOTAL	11.12	2.15	46
	BOYS	11.79	2.43	27
	GIRLS	10.17	1.19	19
1ST GRADE	TOTAL	13.30	2.52	59
	BOYS	14.51	2.09	29
	GIRLS	12.12	2.36	30
2ND GRADE	TOTAL	15.36	3.92	47
	BOYS	18.06	3.87	19
	GIRLS	13.53	2.75	28
3RD GRADE	TOTAL	17.72	2.60	48
	BOYS	19.02	2.41	22
	GIRLS	16.61	2.25	26
4TH GRADE	TOTAL	20.69	3.24	48
	BOYS	22.27	3.08	22
	GIRLS	19.35	2.76	26
5TH GRADE	TOTAL	23.03	5.05	55
	BOYS	25.39	4.42	32
	GIRLS	19.76	3.97	23
ALL GRADES	TOTAL	16.93	5.36	303
	BOYS	18.56	5.77	151
	GIRLS	15.30	4.37	152

Table B - 2

Means and Standard Deviations for Weight (in pounds)

Grade	Total/ Gender	Means	Standard Deviation	Cases
KINDERGARTEN	TOTAL	52.12	7.78	46
	BOYS	53.14	8.62	27
	GIRLS	50.67	6.34	19
1ST GRADE	TOTAL	57.38	7.89	59
	BOYS	59.20	6.40	29
	GIRLS	55.62	8.85	30
2ND GRADE	TOTAL	64.27	12.10	47
	BOYS	68.99	13.67	19
	GIRLS	61.07	9.93	28
3RD GRADE	TOTAL	74.01	14.75	48
	BOYS	71.91	10.02	22
	GIRLS	75.79	17.82	26
4TH GRADE	TOTAL	84.12	16.03	48
	BOYS	80.92	15.34	22
	GIRLS	86.83	16.39	26
5TH GRADE	TOTAL	91.83	18.38	55
	BOYS	95.24	18.83	32
	GIRLS	87.08	16.99	23
ALL GRADES	TOTAL	70.77	19.57	303
	BOYS	72.00	19.68	151
	GIRLS	69.55	19.45	152

Table B - 5

Means and Standard Deviations of the Retest of Grip Strength (in Kg)

Grade	Total/ Gender	Means	Standard Deviation	Cases
KINDERGARTEN	TOTAL	10.87	2.24	45
	BOYS	11.60	2.50	26
	GIRLS	9.88	1.32	19
2ND GRADE	TOTAL	14.83	3.92	45
	BOYS	17.38	3.90	18
	GIRLS	13.13	2.92	27
4TH GRADE	TOTAL	20.94	3.64	47
	BOYS	22.53	3.76	22
	GIRLS	19.53	2.93	25

Table B - 6

Means and Standard Deviations of the Retest of Push-ups (number completed in 30 sec)

Grade	Total/ Gender	Means	Standard Deviation	Cases
1ST GRADE	TOTAL	8.39	5.22	51
	BOYS	8.90	5.20	21
	GIRLS	8.03	5.28	30
3RD GRADE	TOTAL	11.50	9.23	46
	BOYS	15.68	10.38	22
	GIRLS	7.67	6.01	24
5TH GRADE	TOTAL	10.80	7.90	55
	BOYS	11.62	8.25	32
	GIRLS	9.65	7.40	23

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