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Age-related changes in the release point, velocity and acceleration in girls' overarm throwing performance

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Yan, Jin Hong, M.A.

San Jose State University, 1992

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AGE-RELATED CHANGES IN THE RELEASE POINT, VELOCITY
AND ACCELERATION IN GIRLS' OVERARM THROWING
PERFORMANCE

A Thesis

Presented to

The Faculty of the Department of Human Performance
San Jose State University

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

By

Jin Hong Yan

May, 1992

APPROVED FOR THE DEPARTMENT OF HUMAN PERFORMANCE

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APPROVED FOR THE UNIVERSITY

ABSTRACT

AGE-RELATED CHANGES IN THE RELEASE POINT, VELOCITY AND ACCELERATION IN GIRLS' OVERARM THROWING PERFORMANCE

by Jin Hong Yan

Sixty untrained Caucasian girls aged two to seven years volunteered to be subjects in the research project. Each age group (2-3, 3-4, 6-7 years) consisted of 20 subjects. To determine the differences in the release point of girls' overarm throwing performance, all subjects were videotaped in the Biomechanics Laboratory at San Jose State University. The Peak Three-Dimensional Motion Measurement System was used to examine the spatial position of release point, the velocity and acceleration at release. One way ANOVAs indicated that there were significant age-related differences ($p < .05$) in the three dependent variables. Correlation analysis revealed low relationships between release point and the body weight ($r=.20$), height ($r=.19$), and arm span ($r=.19$). Therefore, the findings suggest that under the condition of no training experience in throwing, age is a major factor influencing the release point in girls' overarm throwing performance.

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CHAPTER ONE

INTRODUCTION

Throwing, projecting an object through space by one or both hands (Luedke, 1980), has been studied for more than 50 years. Research seems to have been initiated by Wild (1937), who investigated age and gender differences in children's throwing performance. Because overarm throwing is one of the most important throwing patterns (Burton, Greer, & Wiese, 1991a; Jones, 1951) and the second most common element in physical exercise (Bunn, 1972), since the 1930's, most researchers have concentrated on the overarm throw (Atwater, 1970; Bowne, 1960; Dusenberry, 1952; Halverson & Roberton, 1979; Nelson, Thomas, Nelson, & Abraham, 1986; Wester, 1939). Systematic investigations of the development of overarm throwing, such as throwing patterns, developmental stages, throwing distance, accuracy and velocity, can provide useful information for understanding and facilitating the improvement of throwing skills (Gardner, 1979; Roberton, 1978; Seefeldt, 1980), as well as assisting in the prevention of injuries during the throw (Atwater, 1979).

Generally, research efforts on overarm throwing have focused on four areas of investigation: (1) gender and age differences (Halverson, Roberton, & Langendorfer, 1982; Morris, Williams, Atwater, & Wilmore, 1982; Nelson, Thomas,

& Nelson, 1991); (2) effects of instruction (Dohrmann, 1964; Dusenberry, 1952; Halverson, Robertson, Safrit, & Roberts, 1977); (3) creating an overarm throwing model and determining stages of development (Langendorfer, 1982; Robertson, 1977; 1978); and (4) kinematic characteristics (Anderson, 1976; Singer, 1961; Southard, 1991). The most frequently used measures for overarm throwing were throwing distance and velocity (Atwater, 1979; Robertson, Halverson, Langendorfer, & Williams, 1979; Robertson & Langendorfer, 1980) with more studies favoring throwing velocity (Atwater, 1970; Luedke, 1980; Railey, 1980; Robertson et al., 1979; Wild, 1938). However, some studies (Halverson & Robertson, 1979; Halverson et al., 1977; Leme & Shambes, 1978) suggested that ball velocity itself may not be appropriate to study the development of children's overarm throwing because of its inconsistency.

According to Lindner (1971), a central focus of modern throwing techniques is the release phase. During the release phase, EMG analyses of the major upper body muscles indicated that all muscles are more active than in the earlier phases (Jobe, Moynes, Tibone, & Perry, 1984), and maximal force for body movements is gained and added to the object in the hand (Joris, Edward Van Muyen, Van Ingen Schenau, & Kemper, 1985). Accordingly, the velocity of the moving hand increases

dramatically from the beginning of the forward swing to the release. In addition, different temporal and spatial points of the object in the hand during the acceleration have various velocities. For example, Atwater (1970) found that during the acceleration, the ball velocities increased from less than 20 f/s before release to as high as 112 f/s at release. Also, an acceleration of the throwing hand from 18 to 1200 f/s² was found in children's overarm throws (Wild, 1938). To reach the longest and most accurate landing position, the thrower must maximize the hand velocity and control the projection direction before the release (Atwater, 1979). The point where an object leaves the hand is critical for throwing distance and direction (Miller & Munro, 1983). However, there are no reports in the literature specifically addressing the issue of the release point, and the relationships between the release point and the developmental levels of overarm throwing performance.

Statement of the Purpose

The purpose of this study was to investigate age-related differences in the overarm throwing release point of girls aged two to seven years. Specifically, the study examined age differences in the position of the release point, the ball velocity at release, and the acceleration of the ball at release.

Significance of the Study

According to Bowne (1960), Keogh and Sugden (1985) and Lindner (1971), the release phase is the most important stage in overarm throwing. During this phase, most mature performers rapidly accelerate the actions of the trunk and the arm, as well as the in-hand object (Anderson, 1976; Atwater, 1970; Deutsch, 1969; Wild, 1938). Release point, a particular point in the path of the moving hand in the release phase, has both the spatial and temporal relationship between the projectile and the thrower (Keogh & Sugden, 1985). Release point determines the throwing patterns (Atwater, 1979) and influences the throwing velocity and direction (Keogh & Sugden, 1985; Miller & Munro, 1983). Unfortunately, information is not available about the development of the release point in children's overarm throwing. One major reason is the difficulties in the measurement of the release point. High speed camera and three-dimensional technique are necessary to quantify the release point (Atwater, 1970; Singer, 1961).

Furthermore, in previous studies, questions were raised by some researchers (Halverson & Robertson, 1979; Hanson, 1961; Leme, 1973) about the validity of employing throwing velocity to reflect the development of overarm throwing. Leme and Shambes (1978) indicated that classifying subjects'

arm actions was difficult. Therefore, accurate assessment of the development of overarm throwing is an important issue and needs further study (Halverson et al., 1977). In addition, techniques for throwing velocity measurements have been varied. For example, some researchers (Halverson & Robertson, 1979; Robertson et al., 1979) used a velocimeter (Roberts, 1972), while other researchers employed a sport radar gun (Luedke, 1980), oscilloscope (Railey, 1976), or film-analysis (Robertson, 1987) to measure the throwing velocities. There was no study which compared the results obtained from these devices.

From a biomechanical perspective, a greater distance of acceleration will result in greater velocity. And, if the object is farther from the center of rotation, the linear velocity at end of lever will be greater. In addition, if the human lever is longer, the movement will be more efficient (Kreighbaum & Barthels, 1990). Based on the assumption that throwing skills improve with a longer distal release point, the major significance of this study is to quantitatively describe the release point and reflect the development of children's overarm throwing. Although this is a preliminary study of release point, it may enhance future research on gender differences in release point and effects of instruction on the development of release point. Also, using

the Peak Three-Dimensional Motion Measurement System (Peak Performance Technologies, 1990) to analyze the release point may improve the accuracy of measurements on overarm throwing performance.

Hypothesis

Significant age-related differences in the release point of overarm throwing performance, specifically in the position of the release point, the ball velocity at release, and the acceleration of the ball at release point, will be determined among girls aged two to seven years.

Delimitations

This research was delimited to:

1. subjects who had not received specific throwing training or instruction;
2. subjects from two to seven years of age;
3. subjects who were Caucasian and right hand dominant for throwing;
4. the pattern of overarm throwing;
5. the age-related differences in the position of release point, the ball velocity at release, and the acceleration of the ball at release point; and
6. throws made with standard tennis balls (weight: 2-2 1/2 oz; diameter: 2 1/2-2 5/8"; cover: nap and seam; color: yellow).

Limitations

This research was limited by the following:

1. some subjects, despite their responses, might have received specific training or instruction;
2. some subjects might not have been motivated to throw the tennis balls as hard as possible;
3. some subjects might have been affected by such factors as anxiety and nervousness which might have negatively affected throwing performance in a non-random way;
4. the videotaping was conducted on more than one day; the testing setup might have varied slightly within the bounds of human error; and
5. the study was cross-sectional.

Definitions

The following definitions and operational definitions were used in the research:

1. Acceleration

"The rate of changes in velocity" (Hall, 1991, p.262).

2. Developmental Motor Pattern

An underdeveloped movement pattern used in the performance of a fundamental skill (Wickstrom, 1970).

3. Overarm (hand) Throw

A movement pattern that projects an object with a release point above the shoulder (Luedke, 1980).

4. Release Point (RP)

A spatial position where the object leaves the hand with highest release velocity (Atwater, 1970; Keogh & Sugden, 1985; Singer, 1961; Wild, 1938).

5. Release velocity (Initial)

The velocity at the moment the projectile leaves the hand (Miller & Munro, 1983).

6. Resultant Coordinate (R)

A coordinate that is the effect of three coordinates (X-horizontal, Y-vertical, Z-perpendicular to X,Y) (Kreighbaum & Barthles, 1990).

7. Resultant Velocity (R)

The velocity that is the composition of the velocities in three (X,Y,Z) radiant directions.

8. Resultant Acceleration (R)

The acceleration that is the composition of the accelerations in three (X,Y,Z) radiant directions.

9. Throwing Instruction

Any specific information provided to children or formal practice designed to improve overarm throwing performance.

Summary

Historically, since the 1930's researchers have examined overarm throwing performance (Wild, 1937). Most research has focused on gender and age differences (Nelson et al., 1986),

effects of instruction (Dohrmann, 1964), developmental stages (Robertson, 1977, 1978), and kinematic characteristics (Southard, 1991). Although useful information exists in some areas of application, controversy remains (Halverson & Robertson, 1979). For example, researchers have questioned the validity of the measure of throwing velocity in reflecting the development of overarm throwing (Hanson, 1961; Leme, 1973). Since the release phase has been identified as the most important stage in overarm throw (Bowne, 1960), and the release point influences the throwing velocity and direction (Keogh & Sugden, 1985), scrutinizing the release point is necessary. To fully understand the release phase of children's overarm throwing, age-related differences in the release point in girls' overarm throws were examined in this research.

CHAPTER TWO

REVIEW OF LITERATURE

The purpose of this study was to investigate age-related differences in the release point, release velocity and acceleration of two to seven year old girls' overarm throwing performance. In this chapter, relevant literature concerning overarm throwing performance will be reviewed. The review is divided into four general areas of research on overarm throwing. First, studies examining gender and age differences will be presented. Sections on the effects of instruction and developmental stages will follow. Finally, a section concerning the kinematic characteristics of overarm throwing performance will be reviewed. The chapter will then be summarized.

Gender and Age Differences

Tracing back more than 50 years, Wild (1938) examined ball velocity as it related to age and gender. This classic study is one of the earliest studies examining overarm throwing. Thirty-two boys and girls were selected as the subjects for the study. Film analysis was used to calculate the ball velocity and record the different positions of the body, the arm, and the hand during the throw. The research findings indicated that ball velocity at release increased with age for male and female children. In the course of

acceleration, the ball was released at a certain velocity that varied by age and gender. Regarding the throwing patterns, Wild found that in spite of the differences in ball velocities, releasing the ball from a nearly horizontal path was typical in overarm throwing of children aged 2 to 12 years. The finding was especially significant in older boys' throwing patterns.

In 1982, Halverson et al. conducted a longitudinal research to compare children's horizontal throwing velocity. Roberts' (1972) velocimeter was used to record the data of ball velocity. Thirty-nine children participated in this study. The results indicated that the difference between males and females increased during the elementary school years. From second to seventh grade, the increase slowed and when the children entered seventh grade, the girls' ball velocities lagged behind the boys' by five years. The researchers concluded that, by the age of 13 years, the overarm throw is not fully mature and gender differences exist in both the developmental rates and the potential developmental levels.

In a longitudinal study designed to examine age differences in girls' motor performance (Glassow & Kruse, 1960), girls aged 6 to 14 years were studied for three years. Throwing velocity was measured as an indication

of subjects' throwing abilities. Because the researchers believed that the size of a regular baseball would facilitate younger girls' grasping, a baseball was used in all tests. The results revealed that throwing velocity increased with age. The data indicated that from grades one to five these girls tended to improve their throwing abilities consistently and gradually.

Throwing distance has also been widely used in studies of age and gender differences in throwing performance. For example, research evaluating the fundamental motor performance of children to determine how age and gender affect motor tasks was conducted by Morris et al. (1982). Significant age and gender differences were found for most tasks. Throwing distance tests indicated that boys generally threw farther than girls at all ages. Other motor task tests, however, did not show such an advantage for boys in all age groups. The researchers concluded that age plays a more important role in most motor performance than gender. However, gender affects throwing ability more than age.

To examine the relative contributions of the biological and environmental variables to gender differences in throwing performance, Nelson et al. (1986) measured throwing distance of children's overarm throwing performance and made a comparison between male and female subjects. Boys threw

further and with a more mature technique. In addition, boys were believed to have some biological and environmental advantages, such as greater joint diameters, smaller sum of skinfolds, more arm muscle, and more opportunity to play. Since the data came from five-year-old children, the researchers believed that biological characteristics, such as height, weight, and body mass, contributed to the gender differences in overarm throwing more than environmental variables. Five years later, in a longitudinal follow-up study (Nelson et al., 1991), throwing distance was again measured under the influence of biological and environmental factors. The results indicated that there was still a gap between boys and girls in throwing distance. Boys threw longer and with more mature throwing patterns.

In related research, throwing accuracy tests were used to examine age differences in children's overarm throwing performance. Wester (1939) used male subjects throwing baseballs and volleyballs at a target. By comparing the improvement in throwing accuracy scores of the three age groups, boys in grades three to five were found to improve throwing accuracy significantly each year. Also, the accuracy scores were better at shorter throwing distances than at longer distances. Subjects were more accurate using baseballs than volleyballs.

Effects of Instruction

Instruction and training have been determined to be important environmental factors influencing children's motor development (Thomas & French, 1985). However, conflicting evidence exists. For instance, in a study investigating children's throwing ability as it related to specific training, Dusenberry (1952) found that for children aged three to seven years, training in throwing for distance resulted in gains above the effects of maturation and general practice. This may have been the first study specifically focusing on the effects of training in throwing performance.

In Luedke's research (1980), trained and untrained children in second and fourth grades were provided an instructional program that emphasized increasing the range of throwing movement. The purpose of the study was to examine the effects of the specific instructional program on children's overarm throwing. A sport radar gun was used in the study to record ball velocity. Findings indicated that significant improvement in ball velocities was believed to be the result of the specific instructional program. Also, the subjects' throwing pattern was improved as a result of instruction.

To study the effects of instruction and practice on throwing with the nondominant hand of untrained throwers,

Railey (1976) employed ball velocity as a dependent variable. Twenty-two male college students were tested for throwing velocity using baseballs and an oscilloscope. By comparing the scores of instructional and noninstructional groups, the researcher determined that throwing velocity of the nondominant hand could be improved significantly through instruction and practice.

However, other studies reported that instruction and practice did not significantly produce improvement in throwing performance. For example, Dohrmann (1964) investigated the effects of instruction on eight-year-old children. This research sought to determine when a training program would be most effective. This study specifically examined the influence of instruction on children's performance in throwing distance. Findings indicated that a throwing training program in addition to a regular physical education program did not significantly improve children's throwing distance.

A similar study was conducted by Halverson et al. (1977) to examine the influence of instruction on the development of forceful overarm throwing of kindergarten children. Throwing velocity was used to measure the developmental changes. Comparisons between pre and posttests, and experimental and control groups revealed that significant

differences were determined for both gender and age. However, the instruction and practice did not significantly improve the throwing velocities of the children.

In addition, Robertson et al. (1979) conducted a longitudinal study to examine the development in horizontal ball velocities of kindergarten to second grade children performing the overarm throw for force. One of the purposes was to detect developmental effects of throwing instruction. A Roberts' (1972) velocimeter was used to collect velocity data. The researchers found that boys improved their ball velocities 5 f/s per year, while girls' improvement was 3 f/s a year. The improvement of velocity for both gender was significant. However, throwing instruction did not appear to benefit kindergarten children as determined by the measures of ball velocities at first and second grades.

A study with first grade children yielded similar results (Miller, 1957). In this research, subjects threw rubber playground balls at a target approximately 10 feet away. The results indicated that, the subjects in the experimental groups (instruction) had higher scores than control group subjects (no instruction), though there were no significant differences in accuracy scores between experimental and control groups. Miller suggested that instruction time might be an important factor influencing the

development of children's throwing accuracy.

Developmental Stages

Developmental stages of throwing were initially proposed by Wild (1937). In her study, four developmental patterns were identified for children two to twelve-year olds. Stage one (often exhibited by two to three-year-old children) primarily consisted of forearm extension. The feet do not move and no trunk rotation is exhibited. In stage two, trunk rotation is common in children from three and half to five years. The hand is prepared behind the head; then the trunk rotates to the left (right handed throwers) and the throwing arm swings forward in an oblique-horizontal plane. In stage three, a forward step with the leg on the same side of the throwing arm is added to the pattern (five to six-year-old children). This step creates extra forward force by shifting the body weight forward. However, the range of the backward action of the throwing arm is short. Finally, in stage four, the arm and trunk rotate backward in preparation for the throw. A left foot step moves the body forward, the trunk and shoulder rotate to the left, the elbow swings forward, the forearm extends and the hand releases the ball suddenly (often observed in children aged six and half years or older).

According to Robertson (1977, 1978), a developmental

stage in movement is characterized by a specific movement pattern becoming visible during a specific period of time. This pattern must consistently follow an unchangeable order and can be observed in all people. In a pre-longitudinal study (Robertson, 1977), first grade children were selected to examine stage consistency in the overarm throw. More than half of the subjects' arm actions were graded into the hypothesized stage classification; the rest of the arm actions only varied to the next upper or under ranks. Robertson concluded that the arm categories were stable enough to be deemed stages. However, the trunk categories were not admitted as stages because of their inconsistent assortment. More importantly, by breaking the overarm throw into component parts, an intra-task developmental model was suggested where "development within component parts may proceed at different rates in the same individual, or at different rates in different individuals" (Robertson, 1977, p.55).

In her follow-up study (Robertson, 1978), longitudinal evidence for developmental stages within the humerus, the forearm, and the trunk components of the forceful overarm throw were presented. Cross-sectional and longitudinal analysis indicated that the actions of the humerus, the forearm and the trunk develop from level to level in the

predictable sequences. The stage categories were age-related. In the category of forearm action, three steps were identified: "no forearm lag, partial forearm lag, and full forearm lag" (p.170). The movements of the humerus develop from oblique to horizontal. In the third step, "the humerus lagged slightly behind the trunk" (p.169). For the trunk actions, four steps are: "no trunk action, extension and /or flexion of the trunk, spinal rotation with the pelvis stationary, and block rotation" (p.170).

Motivated by Robertson's (1977, 1978) intra-task stage studies, Langendorfer (1982) attempted to detect the "developmental stage relationship" between overarm throwing and overarm striking. Robertson's (1977) component category and a modified category were used to grade the movements of throwing and striking. By cross-sectional and pre-longitudinal examination, the study indicated that there was a close relationship between throwing and striking in the actions of the forearm, humerus, and trunk. Also, the researcher presented an inter-task model, which suggested that the development of throwing and striking in the same person advances in different skill levels. People become mature in throwing earlier than in striking. This study may have been the first inter-task stage research.

Concerning adult throwing patterns, Leme and Shambes

(1978) conducted a study to examine the possibility that adult women would demonstrate underdeveloped throwing patterns when performing the overarm throw. Film analysis and velocimeter readings (Roberts, 1972) were used for analysis. Also, subjects' throwing movements were assorted by using a modified criterion from Wild's (1937) developmental stages. The results of the study indicated that regardless of the higher velocity scores obtained by most subjects, all adult women in the study were classified as underdeveloped throwers. In addition, significant variances in arm action patterns were identified within the stage and among the stages. Finally, the investigators suggested that age and biological maturation only partially determine the development of motor skills. Further studies are needed to detect the reasons for immature motor patterns across the lifespan.

Roberton and DiRocco (1981) performed research to examine the hypothesis that overarm throwing movements observed in normal children can be identified in the developmental sequences of mentally handicapped children. Film analysis and Roberton's (1977) overarm throwing component category were used to analyze the throwing of 22 mentally retarded boys and girls. The initial throwing velocities were obtained from the films. Despite their

physical weaknesses, most subjects could release the projectiles. The results showed that Robertson's (1977) category was appropriate for the study. The comparison between normal and retarded children revealed that the mentally retarded children develop more slowly than the non-handicapped children and in a different developmental sequence. Using an underdeveloped arm pattern involving a "pushing" action to release the ball was more common for mentally retarded subjects. In addition, their resultant throwing velocities were less than those of normal children.

Other studies have attempted to determine the relationship between movement components and the outcome of throwing performance. For example, in the study by Robertson, Halverson, and Erbaugh (1981), cinematographic techniques and the Roberts (1972) velocimeter were used to examine the relationships between the actions of arm, trunk, feet, and throwing velocity in kindergarten children. Four action components were found to have significant relationships with throwing velocity: forearm, humerus, trunk and the forward step. These actions were believed to contribute 75% of the throw's velocity to the throw. Also, forearm action made up 56% of the velocity of the throw. Thus the researchers believed these actions might be the best components for studying throwing velocity in the overarm throw.

Kinematic Characteristics

According to Kamm, Thelen, and Jensen (1990), a kinematic approach can provide spatial and temporal information about a specific movement. Also, the kinematic approach allows more sophisticated, biomechanical descriptions of the developmental stages (Robertson, 1978). In this part of the literature review, five studies specifically related to the research are presented with more details about kinematic characteristics of the overarm throw, muscle patterning, movement levers, release velocity, and the measurement of the release point.

One of the most detailed and extensive studies of joint actions in the overarm throw was conducted by Atwater (1970). The primary purpose of the study was to determine the differences in the paths and velocity of the ball before release. Subjects performed the overarm throw at three skill levels. Based on the subjects' greatest initial throwing velocities, subjects were subdivided into five skilled college men, five skilled, and five average college women. Triplane cinematographic techniques were employed to simultaneously observe the overarm throwing actions from side, rear, and overhead views. By measuring the three-dimensional displacements, the resultant velocities before release were calculated. The data indicated that three groups

of subjects showed considerable "in-hand" ball acceleration. The resultant velocities increased from less than 20 f/s to the velocities with accelerations of 1500-2000 f/s² for skilled males, 1000 f/s² for skilled females, and 400 f/s² for the average female subjects. Also, all subjects, regardless of their skill levels, released the ball at the point of greatest velocity. An important difference in the arm actions of skilled and average throwers was determined by careful analysis of throwing patterns. Skilled throwers abducted the humerus of the throwing arm to a position approximately in line with the shoulder and remained there until the ball was released. In contrast, the average throwers horizontally adducted the throwing arm to a position in front of the shoulders. This action, combined with trunk rotation, placed the elbow in front of the shoulder of the throwing arm, and caused "elbow extension in a sagittal plane at release" (a "pushing" motion) (p.258).

A similar study was conducted by Anderson (1976) to examine kinematic characteristics of the overarm throw and the tennis serve. Particular focus was placed on the muscle patterning of the movements. Nine women were selected as subjects. This included three skilled throwers, three skilled tennis servers, and three performers with high skills in throwing and tennis serving. Triplane cinematographic and

electromyographic (EMG) techniques were employed in the study. Three 16 mm cameras were used to simultaneously record the side, rear, and overhead views of each movement. Surface electrodes were used to record the electrical activities from the trunk and upper body muscles. Results revealed that there were differences in the patterns of muscle activities between skilled and less skilled performers when they were performing overarm throws. Less skilled performers started joint and muscular activities earlier and maintained them longer during the preparatory and release phases. As throwing skills improved, the performers slightly delayed joint and muscular activities and shortened the time from preparation to the release.

To determine the relationship between some throwing related measures of body levers and the ball velocities of overarm and underarm throws, Bowne (1960) selected 42 high school girls and arranged them into three groups according to their initial throwing velocities. Films and tracings were used to calculate throwing velocities and measure moment-arms of acting levers. Also, standard anthropometric techniques were employed to measure subjects' segment lengths. Since the researcher believed that trunk rotation, arm rotation and flexion, and hand flexion would contribute most to throwing velocity, the trunk, the arm, and the hand were selected as

the levers of interest in the study. The lengths of the moment-arms for all acting levers were determined by measuring the distance from the force applied points to the rotation hinges at the moment the ball left the hand. The segment length was the longest distance between two points in the body segment. Results revealed that there were significant relationships between the moment-arm lengths of acting levers and overarm throwing velocities, especially the trunk and arm levers. No significant relationship was found between segment lengths and throwing velocities. Also, the measurements used in the study were found to be highly reliable. These findings allowed the researcher to conclude that the use of body segments at the moment of ball release is critical to the throwing velocity in the overarm throw. The thrower should, therefore, take full advantage of these acting levers to reach maximum throwing velocity.

More currently, Southard (1991) investigated how release velocity and three major muscles affect overarm throwers' arm actions. In the study, 10 college male students with mature throwing skills were subjects. A WATSMART (Northern Digital) motion analysis system was applied to collect velocity data and to analyze the positions of arm actions. Electromyography (EMG) was used to record electrical activities of the pectoralis major, tricep, and flexor carpi radialis muscles.

To examine the EMG signals, velocity data, and relative positions of the humerus, forearm, and hand simultaneously, a WATSCOPE (Northern Digital) was employed. The subjects were asked to execute five throws in each of four different velocity levels based on their highest velocities (25%, 50%, 75%, 100%). By examining the relative spatial relationships between the hand and the forearm, and how the throwers were taking advantage of arm levers, the differences in arm actions were evident. The results revealed that release velocity and arm action affect each other significantly. Although release velocity and acceleration would increase under the throwers' best efforts, the actions of the forearm and hand were not the same. In other words, the hand's velocity was slower than the other segments. When the throwers performed 75% of the maximum velocity, the throwing efficiency increased; when the throwers performed in full maximum velocity, the throwing efficiency decreased. No significant relationship was found among these muscles in terms of the timing of muscular contraction. Thus the investigator concluded that as the maximum velocity was reached, the slower contraction of the flexor carpi radialis might be the reason for the differences in the arm actions.

According to Singer (1961), overarm throwing can be divided into three phases: the preparatory action, the

forward action, and the release action. To detect the age-related differences in the overarm throw's phases, four girls aged 8 to 11 years were selected as subjects in a longitudinal study. Cinematography was employed to obtain the initial throwing velocity and to analyze subjects' throwing patterns. The feet, the trunk, and the arm were examined in these three phases across years. In each phase, the researcher presented details about the descriptions of the phase and the procedure to determine the phase. For example, the point of release was defined as "the point in time where the ball leaves the thrower's hand" (p.5). Thus the frame in which the ball can be seen separating from the thrower's hand was chosen as the frame for release action study. The findings indicated that when the subjects performed the overarm throw, the three mature throwers with higher throwing velocities had a tendency to widen their strides, increase the scopes of trunk rotation, and hold their humerus close to the horizontal plane. However, the immature thrower with a lower throwing velocity kept her feet stationary, rotated her body slightly, and maintained her humerus over or under the horizontal plane at all times. Although release point was identified in the study, the researcher did not specifically address the age differences in the release point.

Summary

Overarm throwing performance has been studied extensively for more than 50 years. Most of the studies on the effects of instruction, developmental stages and models were conducted from 1950 to 1980 (Dusenberry, 1952; Robertson, 1977, 1978). However, scholars have approached the issues of age and gender differences continuously from 1930 to present. (Nelson et al., 1991; Wild, 1937). The subjects for the research of children's overarm throwing have consisted of one to thirteen-year-old boys and girls. The major techniques for the research included cinematography, Roberts' (1972) velocimeter, and observations. However, the most frequently used measures were throwing distance, accuracy, and velocity. Some studies were longitudinal and some were cross-sectional.

Most throwing related research can be classified in one of four general areas. One group of researchers sought to examine age and gender differences since boys are believed to have biological and environmental advantages in throwing (Nelson et al., 1986). In this area of investigation, boys generally performed better than girls in throwing distance (Morris et al., 1982; Nelson et al., 1986) and velocity (Halverson et al., 1982; Halverson et al., 1977; Robertson et al., 1979). Also, age-related changes were found in initial velocity for both gender (Wild, 1938) and throwing accuracy

for boys (Wester, 1939). In the category of effects of instruction, controversy remains. Instruction was found to improve throwing distance (Dusenberry, 1952) and throwing velocity (Luedke, 1980; Railey, 1976). Yet some studies reported no effects of instruction and practice on throwing distance (Dohrmann, 1964), throwing accuracy (Miller, 1957) and initial velocity (Halverson & Robertson, 1979; Halverson et al., 1977; Robertson et al., 1979). In the research of developmental stages and models, the most popular system to study the processes and developmental stages of overarm throwing were established by Wild (1937) and Robertson (1977). In addition, significant relationships between throwing velocity and some action components were found in the study of Robertson et al. (1981).

Researchers have also conducted studies on certain specific aspects of overarm throwing. For example, Atwater (1970) indicated that before the ball left the hand, the velocity accelerated dramatically. By the time the ball reached the release point, the ball had achieved the highest velocity. Anderson (1976) determined that differences existed in the patterns of muscle activities between skilled and less skilled performers. Skilled throwers initiated muscular activities later and shorter during the preparatory and release phases than the less skilled throwers. Bowne's (1960)

study showed that the length of the moment-arms of the trunk and arm levers significantly influenced overarm throwing velocities. In addition, Southard (1991) applied a WATSMART motion analysis system in his study and found a significant relationship between the release velocity and arm actions. Finally, a procedure to determine the release point in film analysis was proposed by Singer (1961).

In summary, previous studies of overarm throwing have made contributions to "theory-building" (Atwater, 1970; Wild, 1938) and practical application (Nelson et al., 1986; Robertson, 1977, 1978) in the field of motor development. In addition, these studies provide specific information for understanding the development of overarm throwing performance. Although overarm throwing is a classic motor task which has been investigated for more than half a century, much remains to be examined. For example, comparatively less research has been conducted on the development of female children's overarm throwing. Also, there has been not sufficient evidence to support the conclusion that boys outperform girls in the overarm throw. For better understanding of girls' overarm throwing and providing more data for the comparison between males and females, this research project attempted to examine age-related differences in the release point, the release velocity and acceleration in girls' overarm throwing.

CHAPTER THREE

METHODOLOGY

The intent of this study was to investigate age-related differences in the release point of two to seven-year-old girls' overarm throwing performance. In this section, descriptions and details about the subjects, the instruments, the data collection procedures, and the statistical analysis are presented.

Subjects

Subjects were 60 Caucasian girls selected from a volunteer population visiting the Children's Discovery Museum of San Jose and Milpitas Discoveryland. The subjects were untrained right hand dominant overarm throwers. A survey completed by the parent before testing determined the subjects' training experience, dominant throwing hand, and ethnic background (see Appendix A: Preliminary Survey). There were three age groups: (1) two to three years ($\underline{M}=3.1$, $\underline{SD}=.7$); (2) four to five years ($\underline{M}=4.5$, $\underline{SD}=.5$), and (3) six to seven years ($\underline{M}=6.2$, $\underline{SD}=.7$). Each group consisted of 20 subjects. The sample size was determined by using the techniques of Gahlinger and Shifflett (1990) to provide adequate power for the study.

According to Thomas and French (1985), girls have comparatively less opportunity to participate in physical

activity than boys. To limit the training experience, which might affect overarm throwing performance (Dusenberry, 1952; Robertson et al., 1979), only females were examined as a means of controlling for gender differences that have been determined in previous research (Nelson et al., 1986). Also, overarm throwing skills of children younger than 13 years are rarely fully mature (Halverson et al., 1982). To increase the possibility that real differences in the release point would be found, three groups of Caucasian girls with a one-year age difference were chosen. These three age groups were generally determined based on the research of Wild (1937) and her developmental stages of overarm throwing. Children from two to seven years demonstrated differences in overarm throwing patterns (Wild, 1937).

To protect the rights and well-being of subjects in the study, the project was approved by the Human Subjects-Institutional Review Board at San Jose State University. Signed letters of informed consent (see Appendix B: Consent Letter) were obtained from each subject's parents prior to participation in this study. To maintain confidentiality for human subjects, all materials collected were held in a safe place. Only the members of the thesis committee and the researcher had access to the materials.

Instruments

The Projectile

The most common projectiles in overarm throwing studies have been baseballs (Brophy, 1948; Wester, 1939), softballs (Dohrmann, 1964; Seils, 1951) and tennis balls (Gardner, 1979; Morris et al., 1982). However, Burton, Greer, and Wiese (1991b) indicated that bigger balls result in less mature actions of the backswing, the humerus, and the forearm in overarm throwing. To minimize the effects of ball size and weight on the throwing patterns, and to facilitate younger girls' grasping, the lightest and smallest ball, the tennis ball (weight: 2-2 1/2 oz; diameter: 2 1/2-2 5/8"; Cover: nap and seam; color: yellow) was used in the throwing test.

Video Cameras

The purpose of the study and complexity of the tasks involved in analyzing the release point in girls' overarm throwing made it necessary to observe all the throws in two planes (three dimensions). Because the accuracy of the Panasonic AG 450 Camcorder for three-dimensional analysis has been shown to be comparable to that of using 16 mm film (Kennedy, Wright, & Smith, 1989), this camcorder and a Panasonic D-5000 video camera (60 fields/second) were used in the study. To clearly distinguish the release point in overarm throws, a high speed shutter (1/1000 second) was

employed. Because the videotaping was performed indoors and the high speed shutter was set for the cameras, as advised by Peak Performance Technologies (1990), extra lighting was employed. To ensure the two video cameras start scanning new frames at the same time, a camera with a genlock facility was employed. Genlock is accomplished by feeding the video signal from one camera to the genlock input of another camera. Thus these two cameras could simultaneously videotape right side and front views of each subject's throwing.

Peak Performance System

The Peak Performance Motion Measurement System consists of three major components: (1) an IBM AT 286 computer; (2) the video system, including a professional quality VCR (Panasonic AG-639), which captured pictures at 60 fields per second (Hall, 1991), and a professional quality color video monitor (Panasonic CT-1400 MG); (3) the Peak Three-Dimensional software package (Peak Performance Technologies, 1990). The Peak Three-Dimensional Video/Computer Measurement Module contained additional hardware components: (1) a video camera or recorder; (2) calibration frames; (3) a genlock adapter. These additions were necessary for three-dimensional measurement. The system allowed the researcher to obtain and analyze three-dimensional motion data (Peak Performance Technologies, 1990).

The Peak Performance Motion Measurement System has the ability to perform accurate manual digitizing from standard National Television System Committee (NTSC) or Phase Alteration Line (PAL) format video. The system brings the recorded video image to the computer where the related movements are digitized and analyzed. The quantitative data on the positions of the movements, the displacements, velocities and accelerations are available from the kinematic computations (Peak Performance Technologies, 1990). Therefore, the Peak Three-Dimensional System was used to measure the position of the release point, the ball velocity at release, and the acceleration of the ball at release point.

Data Collection Procedures

Videotaping was conducted in the Biomechanics Laboratory of the Department of Human Performance at San Jose State University. Two video cameras were positioned at right angles to each other and centered on the subject. The cameras were approximately 40 feet from the subject to obtain an appropriate depth of field (Peak Performance Technologies, 1990). To facilitate digitizing, the subjects were well illuminated to improve contrast between the subjects and the background to make them as visible as possible (see Appendix C: Testing "Setup"). The study team consisted of two

investigators: a camera operator, and the researcher who gave instructions to the subjects and oversaw testing in general. Pilot work was conducted to enable familiarization with the videotaping procedures, to test the setup (lighting, distance between the cameras, distance between the cameras and subjects), and to correct any errors in the testing design.

Based on a preliminary survey, subjects were randomly selected from the volunteers visiting the Children's Discovery Museum of San Jose and Milpitas Discoveryland. When the permission was obtained from the parents, qualified and selected subjects were invited to the laboratory for testing. They were measured for weight, height, and arm span based on anthropometric standards (Lohman, Roche, & Martorell, 1991).

Two video cameras simultaneously videotaped right side and front views for each subject's throws. All subjects were videotaped individually. To prevent any bodily injuries and make subjects comfortable in the testing environment, five easy effort practice trials, and two medium effort trials were administered to the subjects as warm-up prior to the testing. The subject stood on two marks on the floor to maintain a consistent distance with the comparison point (a three-dimensional block) in front of the subject. When ready, each subject was asked to throw the ball as hard as

she could toward a board on the wall. Only the last three trials emphasizing maximal throwing efforts were videotaped for analysis. The subject was urged to throw the ball "hard" to the board. There were no accuracy requirements, since it has been indicated that as throwing accuracy increases, throwing velocity decreases (Gross & Gill, 1982). No additional instructions were given. Occasionally, extra trials were needed for video records. To identify the subject in the videotapes, a log book was used to record subjects and trials. Testing time for individual subjects averaged five minutes or less. Time efficiency was necessary to maintain cooperation from both the subject and the parent.

Following the videotaping, all video tapes were encoded for digitizing. The data collection was accomplished via the Peak Three-Dimensional Motion Measurement System in the Biomechanics Laboratory of the Department of Human Performance, San Jose State University. To determine the position of the release point, a reference point (the origin of the Calibration Frame) was chosen to measure the distance between the ball at release and the thrower (at X, Y, Z axes). Also, a three-dimensional block was placed on the floor in front of the subject as a comparison point for the measurement. Thus there were 10 points to be digitized in each field: the ball in the hand, the wrist joint, the elbow

joint, the shoulder joint, the hip axis, the knee joint, the ankle joint, the heel, the toe, and the block in front of the subject (see Appendix D: The Spatial Model; Appendix E: Project Setup). The field in which the tennis ball could be seen separating from the subject's hand was chosen for the analysis. The Peak Three-Dimensional Motion Measurement System determined the position of the release point relative to the origin of the Calibration Frame, the ball velocity at release, and the acceleration of the ball at release point. Because the resultant coordinate is the effect of three coordinates (X, Y, Z) (Kreighbaum & Barthels, 1990), and resultant velocity was used in previous research (Atwater, 1970), only the resultant coordinate of release point, resultant velocity at release, and resultant acceleration of the ball at release point were examined.

Statistical Analysis

The statistical test for this study was the one-way analysis of variance. The independent variable was age of the subjects. The dependent variables were the release point, the ball velocity at release, and the acceleration of the ball at release point. Group means and standard deviations for all variables were reported. One-way ANOVAs were conducted to test age-related differences in the three dependent variables. When significance was determined, a Scheffe post

hoc test was used to determine the significance between individual means. Also, the relations between the position of release point and weight, height and arm span were analyzed. The alpha level for this study was .05, and a priori power level was set at .8. The reliability of digitizing was determined by the technique of "digitizing and re-digitizing" and coefficient alpha (Baumgartner & Jackson, 1991).

Summary

The subjects, 60 untrained Caucasian girls from two to seven years of age, were randomly selected from the volunteers visiting the Children's Discovery Museum of San Jose and Milpitas Discoveryland. All subjects were right handed. Each of three age groups (2-3, 4-5, 6-7 years) consisted of 20 subjects. Tennis balls, a Panasonic AG 450 camcorder and a Panasonic D-5000 video camera were employed in conjunction with the Peak Three-Dimensional Motion Measurement System to determine the position of release point, the ball velocity at release, and the acceleration of the ball at release point. The videotaping was performed in the Biomechanics Laboratory at San Jose State University. Digitizing and data collection were completed via the Peak Three-Dimensional Motion Measurement System. One-way ANOVAs were employed to identify age-related differences in the release point, the ball velocity at release, and the acceleration of the ball at release point.

CHAPTER FOUR

RESULTS AND DISCUSSION

The purpose of this study was to investigate age-related changes in overarm throwing release point of girls aged two to seven years. In this chapter, a description of the subjects is presented. Then, results are presented followed by a section discussing age-related differences in each of the dependent variables.

Sample Characteristics

There were 60 Caucasian female subjects ranging in age from two to seven years. None of the subjects had experienced previous training in throwing. Table 1 describes the weight, height and arm span for each age group. Tables 2, 3, and 4 summarize the descriptive characteristics of the three-dimensional data of the position of release point, the velocity at release, and the acceleration at release point. Figure 1 shows the comparison of the three dependent variables (resultant coordinate of release point, resultant velocity at release, and resultant acceleration at release point) among age groups.

Results

To test the hypothesis that age-related differences exist in the spatial position of release point, the ball velocity at release, and the ball acceleration at release

Table 1

Weight, Height and Arm Span of Subjects

AGE(Yrs)	WEIGHT(Pound)		HEIGHT(In)		ARM SPAN (In)	
	Mean	SD	Mean	SD	Mean	SD
2-3	33.15	3.73	36.05	3.43	36.14	3.39
4-5	40.05	6.91	41.40	3.14	41.35	3.15
6-7	52.40	10.51	47.77	3.46	47.80	3.65

Table 2

Three-Dimensional Descriptions for Release Point

Age (Yrs)	RELEASE POINT (meter)							
	X		Y		Z		R	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
2-3	.78	.07	1.5	.12	.31	.08	1.7	.08
4-5	.80	.05	1.5	.14	.28	.10	1.77	.06
6-7	.83	.07	1.6	.11	.32	.13	1.81	.05

X-Horizontal axis; **Y**-Vertical axis;
Z-Perpendicular to X,Y axes; **R**-Resultant coordinate;

Table 3

Three-Dimensional Descriptions for the Velocity at Release

Age (Yrs)	VELOCITY AT RELEASE POINT (meter/second)							
	X		Y		Z		R	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
2-3	.60	.4	.80	.3	.65	.2	1.2	0.5
4-5	.80	.2	1.00	.7	.99	.4	1.6	0.9
6-7	.97	.4	1.60	.9	1.20	.6	2.2	1.1

X-Horizontal velocity at release point;

Y-Vertical velocity at release point;

Z-Velocity at release point(perpendicular to X, Y);

R-Resultant velocity at release point.

Table 4

Three-Dimensional Descriptions for the Acceleration at Release

Age (Yrs)	ACCELERATION AT RELEASE POINT (meter/s/s)							
	X		Y		Z		R	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
2-3	8.4	7.0	13.8	10.1	12.2	10.1	19.7	13.3
4-5	8.6	5.5	19.7	14.5	20.6	12.3	34.7	31.4
6-7	20.2	15.0	34.3	20.3	21.6	13.6	41.4	22.2

X-Horizontal acceleration at release point;

Y-Vertical acceleration at release point;

Z-Acceleration at release point(perpendicular to X, Y);

R-Resultant acceleration at release point.

Figure 1: The Comparison of Three Dependent Variables (resultant coordinate) among Three Age Groups

point, one-way ANOVAs were employed. To maintain the statistical power in the analysis, within the three-dimensional data (X, Y, Z, R), only resultant coordinates of release point, resultant velocity at release, and resultant acceleration of the ball at release point were examined. Also, the relationships between the position of release point and weight, height, arm span were analyzed. Finally, the results of the reliability of digitizing and the actual statistical power of the research are presented.

The Position of Release Point

A significant difference was found in the position of release point among age groups, $F(2,57)=3.63$, $p < .05$. However, when the Scheffe test was used to make comparisons among the age-group means, the only significant difference was between the youngest ($\bar{M}=1.7$ meter) and the oldest ($\bar{M}=1.81$ meter) groups, $t(1)=3.61$, $p < .05$.

The Velocity at Release

The one-way ANOVA determined that there was a significant difference in the velocity at release among age groups, $F(2,57)=7.02$, $p < .05$. The Scheffe follow-up test indicated that significant differences were noted between the youngest ($\bar{M}=1.2$ meter/second) and the oldest ($\bar{M}=2.2$ meter/second) groups, $t(1)=3.71$, $p < .05$; and between the middle ($\bar{M}=1.6$ meter/second) and the oldest ($\bar{M}=2.2$ meter/second)

groups, $t(1)=3.62$, $p < .05$. Table 5 shows that 68% of the subjects released the ball at the highest (peak) velocity during the release phase.

The Acceleration of the Ball at Release Point

Significant differences existed in the acceleration of the ball at release point between the three age groups $F(2,57)=4.12$, $p < .05$. Specifically, significant differences were found between the youngest ($M=19.7$ meter/s²) and the oldest ($M=41.4$ meter/s²) groups, $t(1)=3.83$, $p < .05$. Table 6 shows that, before the release point, 71% of the subjects increased the acceleration of the ball in the hand. Only 29% of the subjects decreased the acceleration before release.

The summary of ANOVAs for the three dependent variables is presented in Appendix F.

Correlation Analysis

The Pearson Product Moment Correlation test indicated low relationships between body height and release point ($r=.19$), arm span and release point ($r=.19$), and body weight and release point ($r=.20$). According to the critical values of correlation coefficients (Thomas & Nelson, 1985), there were no significant relationships between release point and the three biological variables at .05 level of significance.

Reliability and Statistical Power

The reliability of digitizing was determined by the

Table 5

The Percentage of the Subjects Releasing the Ball
at the Highest Velocity

AGE (Yrs)	NUMBER	CASES	PERCENTAGE OF THE SUBJECTS
2-3	20	15	75%
4-5	20	13	65%
6-7	20	13	65%
Total	60	41	68%

Table 6

The Percentage of the Subjects Increasing and
Decreasing the Acceleration before Release

AGE (Yrs)	N	INCREASING	%	DECREASING	%
2-3	20	12	60	8	40
4-5	20	15	75	5	25
6-7	20	16	80	4	20
Total	60	43	71	17	29

technique of "digitizing and re-digitizing" and coefficient alpha (Baumgartner & Jackson, 1991). A high reliability of digitizing was found ($\underline{r}=.97$).

Statistical power of the study was determined by the technique of Gahlinger and Shifflett (1990). The actual statistical power of this research was .90 indicating that the study had a higher chance of making a correct decision.

Discussion

In the present study, significant differences were demonstrated among three age groups in the spatial position of the release point. The older subjects exhibited release points farther from the body than the younger subjects. One reason for the difference in the release point may be related to the developmental changes in subjects' overarm throwing skills or technique. As Wickstrom (1970) indicated, mature subjects throw the ball with a "whip-type" arm action, while immature subjects throw the ball with a "push-type" arm action. Skilled throwers "abduct" the humerus of the throwing arm to a location nearly in line with the shoulder and keep it there until release. Unskilled throwers "adduct" their throwing arm horizontally and release the ball nearly in front of the shoulder. In the present research, most subjects exhibited little to no rotation of their bodies. Typically they only flexed forward in the sagittal plane. Furthermore,

most subjects (58 of 60) did not completely extend their elbows when the ball left the hand (see Appendix G: stick figures). Also, some subjects released the ball from a horizontal path like that described by Wild (1938). Some subjects, however, released the ball from a vertical path, which would influence the release angle, velocity, and acceleration at release. Therefore, the variety of arm actions displayed, coupled with the differences in trunk actions and elbow extension, appeared to produce different spatial positions of release point in three axes (X, Y, Z), as well as affected the velocity and acceleration at release of overarm throwing performance. The second factor influencing the release point may be explained by the biomechanical principles. The older subjects might actively or intentionally take advantage of the longer distance available for hand acceleration, longer distance the ball away from the center of rotation, which would help to achieve greater velocity, acceleration, and more efficient throwing than the younger subjects.

While Nelson et al. (1986) believed that biological characteristics, like weight, height and body mass contribute more to the gender differences in overarm throwing than environmental variables, the present research found no significant relationship between the release point and weight,

height, and arm span within females from two to seven years. This finding is similar to the conclusion of Bowne (1960), who indicated no significant relationship between segment length and throwing velocity. Although the present study did not attempt to examine this question, the results indicated that under a condition of no training, weight, height and arm span did not significantly affect the position of release point. The major factor influencing the release point was the age of the subjects. Age-related development was the primary reason for the differences in the release point.

Similar to the studies of Wild (1938), and Glassow and Kruse (1960), the present research found that throwing velocity at release increased with age. The older subjects gained greater velocity at release. One reason for this may have been that the older subjects with more mature patterns threw the ball more efficiently than the younger subjects. For example, older ones appeared to exhibit greater body rotation than their younger counterparts. Another possible explanation for this result is that the older group was likely to be stronger and had a comparatively longer distance for application of force (to the ball) before release than the younger group. Therefore, the older throwers might apply more force to the ball in the hand during the arm forward action than the younger throwers.

Regarding the velocity at release, two findings were unique to this research: first, most studies only examined horizontal velocity (Halverson et al., 1982; Halverson et al., 1977; Robertson et al., 1979; Wild, 1938). The present study obtained three-dimensional data of the velocity at release. Only resultant velocity at release was analyzed because it is the effect of the velocity in three (X, Y, Z) radiant directions. Second, Atwater (1970) found that all adult subjects in three skill levels released the ball at the greatest velocity. In the present research, 68% of the subjects released the ball at highest (peak) velocity. Since the subjects for Atwater's (1970) study were trained and untrained adult males and females, and the subjects for the present study were untrained female children, the comparison implies that age, gender, and skill-related differences in throwing skill may contribute to the differences in velocity at release. However, this phenomenon needs further investigation.

According to Atwater (1970) and Wild (1938), the acceleration of the ball increased rapidly from forward action to the release point. No study attempted to examine age-related differences in the acceleration of the ball at and before release. The present research determined that significant differences existed in the acceleration of the

ball at release point between age groups. The older subjects displayed greater acceleration of the ball at release point. At the same time, 71% of the subjects increased the acceleration of the ball before release. Again, the level of maturity in throwing and strength were likely to be the major contributing factors. In addition, the ball velocity at release and the acceleration of the ball at or before release point reflect different kinematic characteristics in children's overarm throwing. The acceleration before or at release point demonstrates the process or the rate of velocity changes, while the ball velocity at release is the result or product of the acceleration. High velocity at release does not necessarily mean the acceleration increases consistently from the beginning of forward action to the release point. These two kinematic variables could be examined either together or separately in future research. Since the intent of this study was age-related differences in the ball velocity and acceleration at release point, no attempt was made to examine the relationship between velocity and acceleration of the ball at release point.

Age-related differences were found in the position of release point, the velocity at release, and the acceleration at release point between the three age groups. However, the only significant differences were between the oldest (6-7

years) and the youngest (2-3 years) groups. Two major explanations seem plausible. First, only about half of childhood was covered in this investigation. Second, a one-year age difference between each of the three groups may not have been sufficient to determine developmental differences in the three dependent variables though several conclusions were still projected based on the findings.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to investigate age-related differences in the overarm throwing release point of girls' aged two to seven years. Specifically, the study examined age differences in the position of release point, the ball velocity at release, and the acceleration of the ball at release point. Sixty untrained Caucasian girls from two to seven years of age were randomly selected from volunteers visiting the Children's Discovery Museum of San Jose and Milpitas Discoveryland. Each of three age groups (2-3, 4-5, 6-7 years) consisted of 20 subjects. Three-dimensional analysis was employed to simultaneously observe the overarm throwing actions from the right side and front views. The Peak Three-Dimensional Motion Measurement System was used to determine the position of the release point, the ball velocity and acceleration at release point.

One-way analyses of variance revealed significant age-related differences ($p < .05$) in the position of release point, the velocity at release, and the acceleration of the ball at release point. However, significant differences ($p < .05$) were found only between the oldest (6-7 years) and the youngest (2-3 years) groups in the three dependent

variables. The Pearson Product Moment Correlation showed no significant relationships ($p > .05$) between the release point and body weight ($r = .20$), height ($r = .19$), and arm span ($r = .19$). Also, 68% of the subjects released the ball at their highest velocity during the release phase, and 71% of the subjects increased the acceleration of the ball in the hand prior to release.

Conclusions

1. There are significant age-related differences in the spatial position of the release point. The older subjects released the ball farther from the throwers' bodies than the younger. This dependent variable reflects developmental changes in girls' overarm throwing. Therefore, release point should be used as a developmental indicator of children's overarm throwing performance.

2. Similar to previous studies (Glassow & Kruse, 1960; Wild, 1938), this study found a significant difference between the older and younger subjects in the velocity at release. The older subjects demonstrated greater velocity at release than the younger subjects. However, unlike the study of Atwater (1970), not all subjects released the ball at their greatest velocity.

3. Significant age-related differences were found in the acceleration of the ball at release point. This variable

which was specifically examined for the first time in this research, may be a meaningful indicator to examine kinematic characteristics of children's overarm throwing.

4. No significant relationship exists between the release point and body weight, height, or arm span. These biological variables do not significantly affect the position of release point in girls' overarm throwing. The changes of release point only reflect the development of throwing skills under the condition of no throwing training experience.

5. In general, age-related differences were found in the position of release point, the velocity at release, and the acceleration at release point. Thus the findings suggest that the kinematic variables discussed in this study provide a relatively complete picture of the development of the movement skills in the release phase of girls' overarm throwing performance.

Recommendations

Based on the findings of this research, the following recommendations are made for future research and practical application.

1. Because boys generally outperform girls in overarm throwing (Nelson et al., 1986), detecting gender-related differences in the position of release point, the velocity at release, and the acceleration of the ball at release point is

desirable. Also, age-related differences in boys' release point should be examined.

2. Since the influence of training on overarm throwing remains controversial (Halverson & Robertson, 1979), research should be designed to investigate the effects of instruction or practice on release point, the velocity at release, and the acceleration at release point.

3. The Peak Performance Motion Measurement System was shown to be an effective tool for studying release point. It should also be employed to examine the relationship between the velocity and acceleration at release point. This would facilitate our understanding of the development of throwing skills in overarm throwing release phase.

4. As release angle is so critical for projectile motion, observing the projection angle and release point simultaneously and examining the relationship between these two factors should be a future topic for throwing research.

5. Increasing the age difference between (or among) age groups and examining a variety of subjects from different ethnic backgrounds would provide more information for practitioners.

6. Because release point has been determined to be a factor influencing the throwing velocity and direction (Miller & Munro, 1983), and significant differences in

release point were found in this research, during the instruction or practice of overarm throwing, more attention should be given to the development of release point.

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Appendix A
Preliminary Survey

PRELIMINARY SURVEY

Subject's ID No: _____ Date: ____/____/____

Birth Date: _____ Date of Testing: _____

Race: _____

Dominant Hand: Right Left (circle one)

Length of Training (Throwing): _____ (Month)

Type of Training: _____

=====

Height: _____ (inch) Weight: _____ (pound)

Arm Span: _____ (inch)

(Measured in the Biomechanics Lab at SJSU)

Appendix B

Informed Consent to Participate in Research

This project was approved by the Human Subjects
-Institutional Review Board of San Jose State
University

Informed Consent to Participate in Research

Your child is being invited to participate in research that will investigate age-related differences in the overarm throwing release point. The results of this study will further our understanding of the development of overarm throwing performance and may assist us in becoming better teachers of movement skills.

I understand that

- 1) I will be asked to bring my child to the Biomechanics Lab at SJSU for the overarm throwing testing. My child's weight, height and arm span will be measured. The whole procedure will take about five minutes.
- 2) the possible risks of this study are minimal. However, though highly unlikely, minor injuries can occur with any movement activity.
- 3) the possible benefits of my child's participation are the fun and experience gained from the throwing activity.
- 4) the results from this study may be published, but any information from this study that can be identified with my child will remain confidential and will be disclosed only with my permission.
- 5) any questions concerning the research will be answered by Jin H. Yan at (408) 263-8426. Complaints about the procedures may be presented to Dr. Greg Payne at (408) 924-3028. For questions or complaints about my child's rights, or in the event of research-related injury, contact Dr. Serena Stanford (Associate Academic Vice President for Graduate Studies & Research) at (408) 924-2480.
- 6) my consent is given voluntarily without being coerced, my child may refuse to participate in this study or in any part of this study, and I may withdraw my consent at any time, without prejudice to own relations with SJSU.
- 7) I have received a copy of this consent form for my file.

HAVING READ THE INFORMATION PROVIDED ABOVE, I HAVE MADE A DECISION WHETHER OR NOT MY CHILD MAY PARTICIPATE. MY SIGNATURE INDICATES THAT MY CHILD MAY PARTICIPATE AND IS WILLING TO PARTICIPATE.

_____/_____/_____
DATE

PARENT'S/GUARDIAN'S SIGNATURE

RELATION TO CHILD: _____

PRINT CHILD'S NAME

INVESTIGATOR'S SIGNATURE

Appendix C

Testing Setup (Three-Dimensional Videotaping)

Testing Setup (Three-Dimensional)

Appendix D
The Spatial Model

Spatial Model

Name:	THROW3D			
# of Point:	10			
1	Ball	-	-	-
2	Wrist	1	-	-
3	Elbow	2	-	-
4	Shoulder	3	-	-
5	Hip	4	-	-
6	Knee	5	-	-
7	Ankle	6	-	-
8	Heel	7	-	-
9	Toe	8	-	-
10	Block	-	-	-

Use cursor keys to amend, F3 to file, F4 to set up
Center of Mass. Data are filed. Press CTRL-F2 to
the Main Menu.

Appendix E
Project Setup

<< 3-D Project >>

1	Project Name:	PR3D
2	Spatial Model Name:	THROW3D
3	# of Video Cameras Used (2-5)	2
4	Picture Rate:	60
5	# Pictures Displayed Per Field:	1
6	# Pictures to Skip:	1
7	Frequency Cut-Off for Filter (0 to 23)	6
8	Number of Reference Point (0-2)	1
9	Units of Length (up to 8 characters):	Meters
10	Number of Events (up to 9):	1
11	Event Label # 1:	Release Point

Use cursor keys to amend if necessary, F4 for DLT Set Up.

Appendix F

The Summary of One-Way ANOVAs (Release Point, Velocity at Release, and Acceleration at Release point)

The Summary of Analysis of Variance

Variables	SS	df	MS	F
1. Release Point (R)				
Between	32	2	16	3.63 *
Within	25	57	4.4	
2. Velocity (R)				
Between	11400	2	5700	7.02 *
Within	46317	57	812	
3. Acceleration (R)				
Between	490000	2	247951	4.12 *
Within	240000	57	60165	

* $P < .05$

Appendix G

Samples of Stick Figures

Right Side View of Overarm Throwing

Age: 2-3 years

Age: 4-5 years

Age: 6-7 years