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# A Cinematographical Analysis of the Execution of Three Types of Pitches Using the Windmill Style Softball Delivery

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# A CINEMATOGRAPHICAL ANALYSIS OF THE EXECUTION OF THREE TYPES OF PITCHES USING THE WINDMILL STYLE SOFTBALL DELIVERY

by

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The purpose of the study was to identify the specific kinematic and kinetic variables associated with a successful fast ball, drop ball, and rise ball using the windmill style softball delivery. The subjects chosen for the investigation were female pitchers who participated in the Women's National Fast-Pitch Softball Tournament held in Buffalo, New York from August 17, 1984 to August 24, 1984.

After analyzing the data obtained from these subjects, the investigator concluded that: (a) there is a great deal of variability between the fast ball pitching mechanics of elite windmill style softball pitchers; (b) the success of a drop ball is dependent upon a small degree of hip and shoulder rotation and a large degree of hip and shoulder closure; and (c) the success of a rise ball is dependent upon a large degree of hip and shoulder rotation and a small degree of hip and shoulder closure.

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Bonni L. Kinne

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# CHAPTER I

## INTRODUCTION

Since the invention of softball in 1887, pitching has been an integral part of the game. Kirby (1969) and Jones and Murray (1978) have indicated that a team's success in fast-pitch softball depends greatly upon the skill of the pitcher. In fact, some softball experts have claimed that the pitcher may control 75 - 80% of the game.

Three reasons are usually given for this apparent dominance. First, most pitchers are able to throw the softball at a very high rate of speed. Joan Joyce, once the premier pitcher in the women's game, is reported to have thrown one of her pitches 120 miles per hour (Cooper, Adrian, & Glassow, 1982). Secondly, many pitchers throw four to five different types of pitches. Although the most common types include the fast ball, the drop ball, the rise ball, the curve, and the change-up, some pitchers throw variations of each. Examples of these variations are such pitches as the rise-curve, the slow drop, and the drop-curve. The third reason pitchers appear to control the game of softball is the fact that they pitch off of a pitcher's rubber which is located a relatively short distance from home plate. In women's softball, this distance is 40 feet while in men's softball, the rubber is positioned 46 feet away.

Because pitching is such a major part of the game, softball coaches are continually striving to find new ways to develop young pitching prospects. Unfortunately, some coaches are not exactly certain of the mechanics involved in pitching while others find it difficult to pinpoint flaws in such a rapid ballistic skill. Hopefully, these problems can be eliminated by further research in the area of pitching as well as a more extensive use of videotape for viewing pitching mechanics.

## Statement of the Problem

The problem of the study was to identify the specific kinematic and kinetic variables associated with a successful windmill style softball pitch. During this investigation, the following subproblems were examined.

1. The velocity of the pitch at release.

2. The maximum amount of hip and shoulder rotation which occurred during the execution of a pitch.

3. The maximum degree of foot turn associated with the trail foot during the weight shift and the lead foot at foot plant.

4. The amount of trunk inclination which occurred during the weight shift and at release.

5. The degree of hip and shoulder closure which occurred at release.

6. The length of the subject's stride as compared to her standing height.

7. The amount of torque about the shoulder joint during the arm's downswing and about the wrist at release.

## Purpose of the Study

The purpose of the investigation was to quantitatively describe the mechanics involved in the execution of three types of softball pitches. Specifically, the three pitches analyzed were the fast ball, the drop ball, and the rise ball. It was the investigator's intent that the results of the study would assist interested softball coaches in teaching and understanding the windmill style delivery.

## Need for the Study

Although the literature gave numerous qualitative descriptions of the windmill style softball delivery, very few sources described the motion in quantitative terms. In other words, much of the literature simply expressed the authors' subjective opinions about the basic pitching mechanics. Thus, this study was conducted in an effort to quantitatively describe the delivery in order to provide a further understanding of the windmill pitching style.

## Delimitations of the Study

The study was delimited to the following:

1. The subjects chosen for the investigation were female pitchers who participated in the Women's National Fast-Pitch Softball Tournament held in Buffalo, New York from August 17, 1984 to August 24, 1984.

2. Each subject was instructed to perform three trials of three different types of pitches. Specifically, the pitch selection included fast balls, drop balls, and rise balls.

3. Each subject was asked to determine which one of the three trials represented her best effort. Thus, only one trial of each type of pitch was considered for analysis.

4. The specific kinematic and kinetic variables were analyzed in a two-dimensional field.

## Limitations of the Study

The limitations of the study were as follows:

1. Each trial was performed on a hard track surface. This may have affected a few of the subjects since they

were all accustomed to pushing off of a pitcher's rubber and landing in soft dirt.

2. Because of the relatively poor light conditions in a couple of the films, the ability of the investigator to accurately determine the segmental endpoints of certain body parts may have been affected.

## Basic Assumptions

In this study, the following assumptions were made:

1. The hard track surface did not have an adverse effect upon the subjects' pitching skills.

2. Each subject was able to accurately determine which trial of each type of pitch represented her best effort.

3. The basic pitching mechanics of the left-handed subjects were the same as those of the right-handers.

4. Because the investigation took place near the end of the softball season, all of the subjects were in good physical condition.

5. The subjects chosen for the investigation were representative of the elite pitching population.

## Definition of Terms

The following terms were used in this study:

1. Ballistic skill - a skill used to project an object into the air.

2. Cinematography - the art or science of motion picture photography.

3. Figure-eight style - a softball delivery in which the pitching hand moves through a curved path resembling a figure-eight.

4. Kinematics - a branch of biomechanics which deals with the description of motion.

5. Kinetics - a branch of biomechanics which deals with the causes of motion.

6. Moment arm - the perpendicular distance between the line of action of a given force and the axis of rotation.

7. Moment of inertia - the measure of an object's resistance to a change in angular motion.

8. Slingshot style - a softball delivery in which the pitching arm is brought straight back and then straight forward.

9. Torque - a rotary force which is the product of a given force and the perpendicular distance the force lies from the axis of rotation.

10. Windmill style - a softball delivery in which the pitching hand follows a circular path.

# CHAPTER II

# REVIEW OF LITERATURE

The literature reviewed in this chapter was grouped under the following headings: (a) pitching styles; (b) a qualitative analysis of the windmill delivery; (c) a quantitative analysis of the windmill delivery; (d) types of pitches; (e) cinematography; and (f) summary.

## Pitching Styles

The three types of pitching styles in fast-pitch softball are the windmill, the slingshot, and the figure-eight deliveries. Because the figure-eight style is a generally less effective type of delivery, it is quite unusual to see this pitching style in the higher levels of competition. For this reason, only the two most common types of delivery, the windmill and the slingshot, are discussed in this section.

### The Windmill Pitching Style

The windmill pitching style is the most popular type of softball delivery. One softball expert (Feigner, 1980) stated that windmill pitchers outnumber their slingshot counterparts by a margin of 10:1 while another expert (Kirby, 1975) claimed that the ratio may be as high as

30:1. The windmill style not only requires fewer adjustments with respect to the coordination of body parts, but it is generally less fatiguing (Hofstetter, 1980b; Regitano, 1982). Kirby (1975) stated that it also allows for a greater degree of arm swing. This enables the windmill pitcher to develop good pitch velocity and to conceal the grip better during the execution of a pitch.

## The Slingshot Pitching Style

Although the slingshot pitching style is a less popular type of delivery, it may have some advantages over the windmill style. First, it may allow a more efficient transfer of momentum. This is due to the fact that the slingshot pitcher is better able to align the lead foot with home plate during the execution of a pitch (Kirby, 1975). The slingshot pitcher may also have a slight advantage in terms of the batter's familiarity with the pitching motion. Because the slingshot delivery is seen less often in competition, it may take some time for the batter to become accustomed to hitting against a slingshot pitcher (Feigner, 1980; Kirby, 1975).

Although the windmill delivery is preferred by a greater number of pitchers, both pitching styles have been used with equal effectiveness in softball competition. The selection of a pitching style, then, should not be dependent upon popularity. Instead, a young pitcher should be permitted to use the delivery which feels most natural (Drysdale & Harris, 1982).

## A Qualitative Analysis of the Windmill Delivery

The windmill pitching style is usually divided into three major movement phases. In the preparation phase (Higgins, 1977; Kreighbaum & Barthels, 1981), the body is moved from a static starting position into a position which allows for proper execution of the pitch. The execution phase (Kreighbaum & Barthels, 1981) or operation stage (Higgins, 1977) is that portion of the delivery in which the body is moved in such a way as to accomplish the purpose of the task. Finally, the recovery phase (Kreighbaum & Bathels, 1981) or return stage (Higgins, 1977) is known as the follow-through. During the follow-through, the body is returned to its original static state.

In order to be successful, a pitcher must use proper mechanics during each one of these phases. The important mechanics involved in each phase are presented in this section.

The Preparation Phase

To begin the delivery, the pitcher's feet are placed approximately shoulder width apart with the heel of the trail foot in contact with the front half of the pitcher's rubber and the toes of the lead foot in contact with the back edge. This positioning of the feet provides a greater distance over which forward momentum can be generated (Drysdale & Harris, 1982; Feigner, 1980; Hay, 1978; Kirby, 1975). In addition, the pitcher stands with the weight on the back foot and the shoulders in line with first and third bases. Although Hofstetter (1980a) and Kirby (1969) emphasized that the toes of both feet should be pointing towards home plate during this initial stance, Feigner (1980) stated that the front foot should be turned slightly to the throwing arm side and the back foot pointed slightly in the opposite direction in order to facilitate proper hip and shoulder rotation later in the pitching motion.

In addition to having both feet in contact with the pitcher's rubber and the shoulders in line with first and third, the pitcher must also hold the softball in one hand (Official 1984 Softball Rule Book, 1983). Once the signals have been received from the catcher, the ball may then be held with both hands for one to ten seconds prior to the beginning of the windup. It is during this period that the pitcher grips the softball in one of several ways depending upon the type of pitch that needs to be thrown. If the pitcher wants to pitch a fast ball, the ball is gripped near the ends of the first two fingers. By maximizing the length of the moment arm associated with the wrist joint, this grip increases the potential contribution of the wrist snap to the velocity of the pitch (Drysdale & Harris, 1982; Feigner, 1980; Kirby, 1969, 1975). The pitcher also holds the softball firmly across the seams. Because the seams increase the friction between the fingers and the ball, this type of grip reduces slippage and increases control (Drysdale & Harris, 1982). If the pitcher wants to throw a pitch other than a fast ball, the softball must be gripped in a different manner. The grips associated with the drop ball and rise ball are discussed in a later section of this chapter.

The actual delivery of the pitch begins when the pitcher leans forward and places all of the weight on the front foot. As this weight shift occurs, the front foot is turned in the direction of the throwing arm side. This outward rotation of the foot not only facilitates proper hip and shoulder rotation, but it also allows the pitcher to push in a nearly horizontal direction against the pitcher's rubber (Drysdale & Harris, 1982; Kirby, 1975). According to Leviton (1963), "the pitcher pushes against the pitching plate and the ground with a force equal to that which propels him forward - Newton's Third Law" (p. 44). Next, the pitcher begins to move the lead foot in the direction of the target and the pitching arm in its circular windmill path. Alexander (1978) emphasized the importance of coordinating these two actions. It is also essential that the pitching arm be kept straight, though not stiff, throughout the entire windmill delivery (Hofstetter, 1980b; Kirby, 1969; Leviton, 1963). This increases the length of the pitcher's lever arm and, as a result, increases the shoulder's contribution to the velocity of the pitch (Kirby, 1969; Northrip, Logan, & McKinney, 1983). After all, "the longer the lever, the greater the speed at the end of the lever" (Latchaw & Egstrom, 1969, p. 25).

Although the preparation phase actually overlaps with the execution phase (Kreighbaum & Barthels, 1981), the conclusion of the preparation phase may be thought of as that point in the delivery just prior to foot plant. At this time, the pitching arm is beginning its downward motion, and the hips and shoulders are rotated so the body faces sideways. This side orientation not only places the body in a position where hip and spinal rotations can contribute to the velocity of the pitch, but it also increases the distance over which the softball travels prior to release (Hay, 1978). The positioning of two other body parts is also extremely crucial at this stage of the delivery. First, the wrist must be hyperextended and must remain in that position until the instant just prior to release (Drysdale & Harris, 1982; Hofstetter, 1980b). Secondly, the "free arm" must attain a position parallel to the ground with the "glove hand" pointing in the direction of the target (Drysdale & Harris, 1982; Feigner, 1980; Kirby, 1975). This assists the pitcher in maintaining balance (Drysdale & Harris, 1982; Jones & Murray, 1978). Throughout the remainder of the delivery, then, this arm moves in the opposite direction of the pitching arm (Feigner, 1980; Jones & Murray, 1978; Kirby, 1975).

## The Execution Phase

The execution phase begins as the lead foot is planted and the pitching arm reaches a horizontal position behind the body. Although Kirby (1969, 1975) and Regitano (1982) stated that the lead foot should be planted in alignment with home plate, Hay (1978) claimed that maximum hip rotation may be attained if the foot is planted slightly off-line in the direction opposite the throwing arm side. Hofstetter (1980a), Regitano (1982), and Walsh (1977) all agreed that the lead foot should point directly towards home plate at foot plant while Kirby (1975) emphasized that the "placement of the striding foot at an angle is not completely detrimental" (p. 88). Although some controversy exists as to the placement of the lead foot, all seem to agree that it is extremely important for the pitcher to flex at the hip, knee, and ankle joints as the lead foot is planted (Drysdale & Harris, 1982; Feigner, 1980; Kirby, 1969, 1975). Not only does this assist in the absorption of shock, but it also enhances the pitcher's chances of throwing a strike. Kirby (1969) stated that "this is because the pitcher is better able to concentrate his eyes on the target. The arc formed by the pitching hand is also leveled out more because of this giving at the joints" (p. 64). In other words, by flexing at the hip, knee, and ankle as the lead foot is planted, the pitcher is able to flatten the arc of the ball's path as it reaches the release point (Barham, 1978; Broer, 1968; Broer & Zernicke, 1979; Greenlee, Heitmann, Cothren, & Hellweg, 1981; Luttgens & Wells, 1982). After all, "flattening the arc of the ball's path prior to release increases the margin of error by allowing more time over which the ball can be released in the desired direction" (Luttgens & Wells, 1982, p. 516).

Once the lead foot has been planted, the pitcher begins to rotate the hips and shoulders so they are square to home plate at release (Hofstetter, 1980a, 1980b). As the ball reaches the release point, the pitcher's upper body is perpendicular to the ground or bent slightly backwards (Kirby, 1969, 1975). Finally, a split second prior to releasing the pitch, the pitcher snaps the wrist forward and upward. Regitano (1982) stated that this wrist snap may add as much as 10 miles per hour to the pitcher's fast ball.

The actual release, then, marks the conclusion of the execution phase and the beginning of the recovery phase. For a fast ball, the pitcher releases the softball at a height midway between the hip and knee joints as the pitching arm becomes perpendicular to the ground (Claflin, 1978; Drysdale & Harris, 1982; Feigner, 1980; Hay, 1978; Kirby, 1975). Thus, the ball is released just after it passes by the trail leg (Alexander, 1978).

### The Recovery Phase

The recovery phase, or follow-through, begins at the instant of release. During this phase, the trail leg is swung forward until it is positioned alongside the lead leg (Feigner, 1980; Jones & Murray, 1978; Kirby, 1975). The pitching arm continues forward and upward until it reaches shoulder height (Feigner, 1980). At the end of the follow-through, the pitcher should be facing home plate, and the "glove hand" should be out in front of the body.

Although the follow-through does not directly affect the speed or direction of a pitched ball (Bunn, 1972; Leviton, 1963), it is carried out for a number of reasons. First, it assures that the pitching arm does not lose any velocity prior to release (Alexander, 1978; Drysdale & Harris, 1982). If an attempt was made to stop the arm motion at release or immediately afterwards, the pitcher would have to slow down the speed of the pitching hand prior to releasing the softball (Broer & Zernicke, 1979; Logan & McKinney, 1977). As a result, the velocity of the pitch would be reduced. Broer (1968) summed this up by stating, "while the follow-through of a movement takes place after the object has been released, it affects the object because of its effect on the movement which precedes the release" (p. 69). Another reason the follow-through is used is to reduce the risk of injury (Alexander, 1978; Broer & Zernicke, 1979; Bunn, 1972; Drysdale & Harris, 1982; Hay, 1978; Leviton, 1963; Logan & McKinney, 1977). A great deal of strain would be placed upon the arm if the pitching motion was stopped immediately after the release of the pitch. Finally, the follow-through places the pitcher in a good fielding position should a ball be hit towards the mound

(Alexander, 1978; Bunn, 1972; Leviton, 1963; Logan & McKinney, 1977). In other words, "his job is not necessarily finished with the release of the ball" (Logan & McKinney, 1977, p. 227).

## A Quantitative Analysis of the Windmill Delivery

Although most of the literature described the windmill pitching style in qualitative terms, a few sources attached quantitative values to certain aspects of the delivery. Specifically, quantitative analyses of the following variables were given: (a) stride length; (b) torques about the shoulder and wrist; and (c) the contribution of various joint actions.

### Stride Length

Two studies were found which dealt with stride length and its effect upon a windmill pitcher's success. In one study, Zollinger (1973) reported that the average stride length of one windmill pitcher was 69% of the subject's standing height. In another study, Alexander (1978) measured the stride lengths of four fairly successful pitchers and, like Zollinger, converted these lengths to percentages of the subjects' standing heights. In this study, the percentages were reported to be 52.79%, 61.97%, 68.22%, and 80.90%. Although the range of percentages in

Alexander's investigation was quite high, "studies do show that good performers take longer steps than those who are less skilled and that the length of the step is a feature that distinguishes between good and poor performers" (Cooper, Adrian, & Glassow, 1982, p. 242). After all, a short stride may reduce a pitcher's ability to rotate the hips and shoulders and may cause undue strain on the pitching arm (Hofstetter, 1980a).

## Torques About the Shoulder and Wrist

One researcher (Zollinger, 1971, 1973), during her investigation of the windmill style softball delivery, found that the velocity of a pitch was directly related to the magnitude of the torque about the shoulder during the arm's downswing and the amount of torque about the wrist at release. Although an additional torque, that which occurs about the radio-ulnar joint, contributes to the spin of the softball, Zollinger claimed that it did not affect the ball's velocity.

During her investigation, Zollinger studied the pitching mechanics of a highly successful female pitcher. At the end of the study, she reported that the torque about the shoulder was 109.12 foot-pounds and the torque about the wrist was 38.74 foot-pounds. In other words, the torque about the shoulder was 2.8 times greater than that about the wrist. Another interesting finding in this investigation was that as the pitching hand approached the release point, the torque about the shoulder was -210.72 foot-pounds. Zollinger (1971) claimed that "the negative value denoted a reversal of the arm muscles' force. The arm was slowing down so that the wrist action could take place" (p. 14).

## The Contribution of Various Joint Actions

Two studies were found which dealt with the contribution that various joint actions make to the velocity of a windmill pitch. In one study, Cooper et al. (1982) reported that "one finds the contribution of the joint actions (expressed in percentages) to be as follows: hip, 14.3; spine, 7.9; shoulder, 45.3; wrists, 32.4" (p. 250). In another study, Gowitzke and Milner (1980) found that pelvic rotation made a 16.4% contribution to the velocity of the pitch; spinal rotation, a 9.9% contribution; shoulder flexion, 36.79%; wrist flexion, 25.6%; and sternoclavicular protraction, 12.10%. In both studies, then, shoulder flexion appeared to be the major contributor to the velocity of the softball at release.

## Types of Pitches

The most popular types of softball pitches include the fast ball, the drop ball, the rise ball, the curve, and the change-up. The mechanics associated with pitching a fast ball have already been discussed in the previous two sections of this chapter. In this section, some important aspects of the drop ball and the rise ball are compared and contrasted.

### Spin

When a pitcher applies spin to a pitch, this action causes the softball to curve in a certain direction on its way to the plate. The amount that the softball curves is dependent upon both the velocity of the pitch and the amount of spin applied (Bunn, 1972; Hofstetter, 1980c).

In the case of a drop ball, the pitcher releases the pitch so the softball has top spin. In other words, the top half of the ball is spinning forward while the bottom half is moving backwards. Because the bottom half is moving in the same general direction as the oncoming air flow, the velocity of the air moving past the bottom half of the ball is greater than that which flows over the top half. Thus, a low pressure area develops underneath the softball (Barham, 1978; Brancazio, 1984; Broer, 1968; Broer & Zernicke, 1979; Cooper et al., 1982; Hay, 1978;

Hinson, 1981; Kreighbaum & Barthels, 1981; Luttgens & Wells, 1982; Piscopo & Baley, 1981). This phenomenon is in accordance with Bernouilli's Principle which states that "fluid pressure is decreased whenever speed of flow is increased" (Cooper et al., 1982, p. 74). The softball, then, moves in the direction of least air resistance. In this case, the top spin causes the ball to drop.

The rise ball, on the other hand, is thrown with back spin. In other words, the top half of the softball is moving backwards in the same direction as the oncoming air flow. As a result, a low pressure area develops over the top of the ball, and the ball appears to be deflected upwards.

In general, then, "the ball curves toward the same direction that the front of the ball is turning" (Brancazio, 1984, p. 370). Because a German physicist named Magnus first explained why spinning balls follow a curved path, this phenomenon has since become known as the Magnus effect (Barham, 1978; Brancazio, 1984; Hay, 1978; Luttgens & Wells, 1982).

## Grips

There are a few general rules governing the way in which the drop ball and rise ball are held. First, both types of pitches should be gripped very firmly (Drysdale

& Harris, 1982; Feigner, 1980; Kirby, 1975). This enables the pitcher to impart maximum force to the ball in the intended direction. Feigner (1980) indicated that the rise ball should be held even more firmly than the drop. Another general rule is that the softball should be held deep in the palm (Drysdale & Harris, 1982; Feigner, 1980; Jones & Murray, 1978; Kirby, 1975). This increases the distance over which the ball can roll prior to leaving the pitcher's hand. Consequently, more spin can be applied. Finally, the pitcher should grip the ball so the greatest number of seams and the greatest seam length will meet the oncoming air flow since it is the interaction of the seams and the air flow which helps to generate the low pressure area on one side of the softball (Drysdale & Harris, 1982; Feigner, 1980; Kirby, 1975).

In addition to these general rules, there are a couple of specific rules dealing with each type of pitch. For example, the drop ball is normally held with two or three fingers across the seams (Guenzler, 1979; Hofstetter, 1980c; Jones & Murray, 1978; Walsh, 1977). Furthermore, most drop ball pitchers prefer gripping the seams with only the tips of their fingers (Walsh, 1977). The rise ball, on the other hand, is usually held with two fingers placed along the seams (Guenzler, 1979). In addition, many rise ball pitchers tuck their index finger or place a knuckle on one of the seams (Guenzler, 1979; Walsh, 1977). According to Walsh (1977), however, "there is no one best way to grip the ball for throwing a certain pitch. . . . Actually the grip is second in importance to the proper rotation" (p. 29).

Stride Length

It appears that a shorter stride is necessary in the execution of a drop ball while a longer stride is essential when pitching a rise (Drysdale & Harris, 1982; Guenzler, 1979; Hofstetter, 1980c, 1980d; Regitano, 1983; Schroder & Hinderliter, 1981). In one study, Guenzler (1979) measured the stride lengths of five male windmill pitchers. He then converted these lengths to percentages of the subjects' standing heights and percentages of their leg lengths. In each case, the percentages obtained for the rise ball were greater than those obtained for the drop.

Arm Actions

Guenzler (1979) studied the different arm actions which occurred when executing the drop ball and the rise. Based upon this study, he concluded that the drop is thrown most effectively when the arm and hand are supinated at release. Thus, the palm of the hand faces the target as the softball is rolled off the fingertips. The rise ball delivery, on the other hand, is characterized by forearm supination and lateral rotation of the shoulder during the arm's downswing followed by ulnar deviation at the wrist as the ball is released.

## Release Point

Although Hofstetter (1980c, 1980d) claimed that the drop ball is released at a point near the hip and the rise is released as close to the knee as possible, Guenzler (1979) obtained contradictory results when he studied the pitching mechanics of five male windmill pitchers. In his study, Guenzler found that the drop ball is released closer to the knee while the rise ball is released at a point nearer the hip. Guenzler also examined the release point in the horizontal direction. During this investigation, he discovered that the rise ball is released as the pitching hand approaches a position directly below the subject's chin. The drop ball, on the other hand, is released prior to the pitching hand reaching this position.

## Velocity of the Pitch at Release

Both Guenzler (1979) and James (1971) agreed that an average drop ball is released with more initial velocity than a typical rise ball. In Guenzler's investigation, the five subjects pitched the drop ball at an average speed of 100.3 feet per second while they threw the rise at an average speed of 96.9 feet per second. James, meanwhile, conducted a study involving three male windmill pitchers. These subjects pitched the drop ball at an average speed of 86.7 feet per second and the rise ball at an average speed of 85.1 feet per second. James (1971) concluded that "the slower velocity rise ball was probably due to the greater amount of energy used to impart spin on the ball to make it rise" (p. 30).

## Cinematography

Etienne Jules Marey and Eadweard Muybridge are the two individuals generally credited for creating an interest in the study of human movement (Cited in Cooper et al., 1982). As a direct result of their early research efforts, cinematography began to be used by physical educators in an attempt to enhance the performances of a variety of motor skills. In this section, the following areas of cinematography are discussed: (a) the hierarchy of analyses; (b) cinematographic analysis equipment; and (c) filming procedures.

## The Hierarchy of Analyses

There are four levels in the hierarchy of biomechanic analyses (Logan & McKinney, 1977; Northrip, Logan, & McKinney , 1983). These levels include:

1. Noncinematographic analysis.
2. Basic cinematographic analysis.
3. Intermediate cinematographic analysis.
4. Biomechanic research.

Noncinematographic analysis is the most frequently used analysis procedure while biomechanic research is the most sophisticated. Each of these four levels is described in this section.

### Noncinematographic Analysis

As the name implies, noncinematographic analysis uses neither film nor videotape (Logan & McKinney, 1977; Northrip et al., 1983). Although rapid ballistic skills are very difficult to observe with the naked eye, this analysis procedure is used in the observation of all types of motor skills. During the analysis of a skill, the physical educator observes the performance a number of times. Thus, the attention is focused on the movement of a different body part during each observation. Once a fault has been detected in the performance, the physical educator should positively communicate suggestions on ways to improve.

## Basic Cinematographic Analysis

Basic cinematographic analysis involves the use of film or videotape (Logan & McKinney, 1977; Northrip et al., 1983). Thus, this technique eliminates some of the guesswork which was present in the noncinematographic procedures. In other words, "film allows the observer to see what has actually occurred as contrasted with what he or she thought took place within the moving joints of the performer" (Northrip et al., 1983, p. 11). Film also allows the physical educator to retain a permanent record of the performance. Although basic cinematographic analysis does not involve any mathematical computations, it is a valuable tool used in the evaluation of many motor skills.

## Intermediate Cinematographic Analysis

Intermediate cinematographic analysis involves some mathematical computation (Logan & McKinney, 1977; Northrip et al., 1983). Specifically, this analysis procedure is used to calculate such things as joint angles, linear velocities, angular velocities, and accelerations. As a result, more care must be taken during the filming of the performance.

Biomechanic Research

This level in the hierarchy of biomechanic analyses involves very sophisticated equipment found only at a small number of universities across the United States (Logan & McKinney, 1977; Northrip et al., 1983). This high level equipment includes such items as high-speed cameras, electrogoniometers, force platforms, electromyographic devices, stroboscopic devices, and computers.

Cinematographic Analysis Equipment

In order to conduct a cinematographic analysis project, proper equipment is necessary. Specifically, this essential equipment includes: (a) cameras and lenses; (b) film; and (c) data analysis systems. Each of these is described in this section.

Cameras and Lenses

The most common type of camera used in the study of human movement skills is a 16 millimeter camera capable of speeds up to 500 frames per second (Higgins, 1977; Miller & Nelson, 1973; Piscopo & Baley, 1981). Although both spring-driven and motor-driven cameras are available, the motor-driven models are preferred (Logan & McKinney, 1977; Miller & Nelson, 1973; Piscopo & Baley, 1981; Taylor, 1971). Motor-driven cameras maintain more consistent frame rates and are not adversely affected by temperature and humidity (Miller & Nelson, 1973; Piscopo & Baley, 1981). The only disadvantages to motor-driven cameras are their expense and their need for a power source (Logan & McKinney, 1977; Taylor, 1971).

An interchangeable lens system is recommended for cameras used in cinematographic analyses. This lens system would include: (a) a standard lens with f/stops ranging from 1.9 to 22; (b) a wide-angle lens with f/stops of 1.8 to 16; and (c) a telephoto lens with f/stops ranging from 2.5 to 32 (Logan & McKinney, 1977; Piscopo & Baley, 1981). A telephoto lens with zoom capabilities is essential, because it allows the camera to be positioned farther away from the subject without losing any of the details of the performance (Logan & McKinney, 1977; Miller & Nelson, 1973; Piscopo & Baley, 1981). This greater camera-to-subject distance also minimizes the amount of perspective error present. Perspective error, as defined by Miller & Nelson (1973), is that "which occurs when parts of the body or sports implements lie outside the principal photographic plane" (p. 128).

## Film

Film manufacturers rate films according to their sensitivity to light by giving each type of film an ISO/ASA index value. Those films which are most sensitive to light are known as "fast" films and are given high index values (Mercer, 1971; Miller & Nelson, 1973; Piscopo & Baley, 1981). Therefore, the choice of film depends upon such factors as the light conditions, the film speed, and the type of camera used (Logan & McKinney, 1977; Piscopo & Baley, 1981).

## Data Analysis Systems

According to Barham (1978), "digitizing systems, used to put visual images into digital or numerical form, can be classified as those that involve (1) paper and pencil procedures, (2) mechanical devices and procedures, and (3) electronic devices and procedures" (pp. 27, 30).

The paper and pencil procedures are the simplest forms of analysis. After projecting the film's images onto a flat surface, the researcher either traces the contour of the subject's body or uses the point-and-line technique to obtain a stick figure drawing (Barham, 1978; Cooper et al., 1982; Piscopo & Baley, 1981).

The mechanical digitizing procedures involve the use of a motion analyzer which gives digital data that can be mathematically analyzed at a later date. Logan et al. (1977) stated that there are several things to look for when selecting a motion analyzer. First, it should be pin registered and should have a single frame advance feature as well as forward and reverse capabilities at many different speeds. It should also possess constant illumination and focus. Finally, it should have a frame counter and a feature which prevents the film from being damaged by heat.

Electronic devices are those data analysis devices which are directly interfaced with a computer (Barham, 1978). Logan & McKinney (1977) stated that these devices automatically feed digital data into an on-line computer. The computer is then used to calculate such things as center of gravity values and velocity and acceleration data.

Filming Procedures

Luttgens & Wells (1982) stated that "when filming is done for research purposes, the camera needs to be centered with respect to the action, stationary, level, and perpendicular to the motion plane" (p. 422). In addition to proper camera placement, the researcher must be concerned with two other important items. First, some type of reference measure is necessary in order to allow the researcher to convert film measurements to actual distances (Gombac, 1968; Grieve, Miller, Mitchelson, Paul, & Smith, 1975; Miller & Nelson, 1973; Northrip et al., 1983; Plagenhoef, 1971; Taylor, 1971). This reference measure could be a large grid screen placed in the background or a small grid built into the lens of the camera (Taylor, 1971). An even better reference measure may be an object of known length which is photographed as it is held in the plane of the motion. This reference measure would then be removed from the area prior to filming the performance (Gombac, 1968; Grieve et al., 1975; Miller & Nelson, 1973; Taylor, 1971). The second concern of the researcher is the operating speed of the camera. One way to calibrate this camera speed is to include some type of timing device in the photographic field while the filming is taking place (Grieve et al., 1975; Miller & Nelson, 1973; Northrip et al., 1983; Plagenhoef, 1971; Taylor, 1971). The other way to check the camera's operating speed is to purchase a camera with a built-in timing light (Miller & Nelson, 1973; Taylor, 1971).

## Summary

In this chapter, both qualitative and quantitative descriptions of the windmill pitching style were presented. In addition, some important aspects of the drop ball and rise ball were compared and contrasted. It was discovered that the drop ball was characterized by a top spin motion and a high initial velocity. In order to throw this pitch most effectively, the pitcher should grip the ball across the seams, take a short stride, supinate the arm and hand, and release the pitch sooner than usual. The rise ball, on the other hand, was noted for its back spin motion and its slower initial velocity. To successfully throw this type of pitch, the pitcher should grip the ball along the seams, take a longer stride, supinate the forearm and laterally rotate the shoulder, and release the pitch once the pitching hand reaches a position directly below the chin.

The end of this chapter dealt with the hierarchy of biomechanic analyses, the equipment necessary to conduct a cinematographic study, and the filming procedures used in a cinematographic investigation.

# CHAPTER III

# EXPERIMENTAL PROCEDURES

The problem of the study was to identify the specific kinematic and kinetic variables associated with a successful fast ball, drop ball, and rise ball using the windmill style softball delivery. The procedures used in the investigation were grouped under the following headings: (a) subjects; (b) instrumentation; (c) filming procedures; (d) data analysis procedures; and (e) statistical analysis procedures.

## Subjects

The subjects chosen for the investigation were 18 female pitchers who participated in the Women's National Fast-Pitch Softball Tournament held in Buffalo, New York from August 17, 1984 to August 24, 1984. The subjects were invited to participate in the study based upon their pitching records and upon the investigator's subjective analysis of their respective skill levels. Thus, only the most highly skilled pitchers were selected. The subjects who consented to the study did so with the understanding that the filming would take place at their convenience. In addition, all of the coaches had to approve of their pitchers' participation in the investigation.

Of the 18 subjects, 13 were right-handed windmill style pitchers, 3 were left-handed windmill style pitchers, and 2 were right-handed slingshot style pitchers. Only the data produced by the windmill pitchers were considered for analysis.

## Instrumentation

The two cameras employed in the study were Photo-Sonics Biomechanics 500 cameras, model 1-PL, equipped with 12 - 120 mm lenses. One of the cameras, called the sagittal camera, was placed parallel to the pitching rubber, 39 feet, 3 inches away from the plane of the subject. The other camera, called the frontal camera, was located behind the catcher at a distance of 65 feet from the plane of the subject. Both cameras were set up at a height of 3 feet, 7-1/4 inches during the first day of filming. The height of the frontal camera was changed to 3 feet, 7-3/4 inches during the second and third days. Figure 1 represents a schematic diagram of the filming site illustrating the camera placements for a right-handed pitcher.

During the filming procedures, both cameras were set at 150 frames per second. The settings of the shutter angle and the f/stop varied periodically due to the changing light conditions. The film used in the study

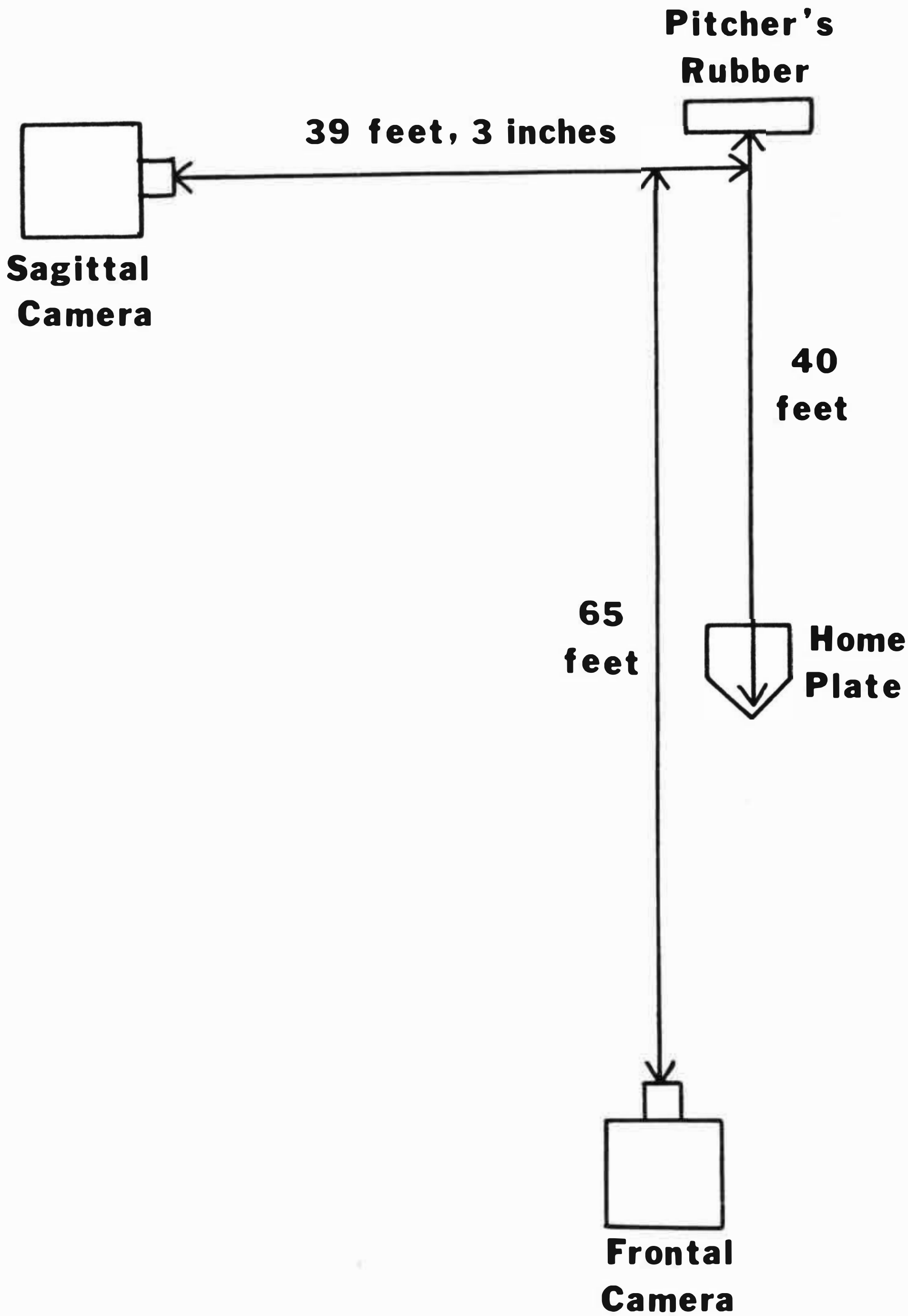


Figure 1. A schematic diagram of the filming site illustrating the camera placements.

included: (a) five rolls of Eastman Ektachrome Commercial Film 7252; (b) three rolls of Eastman Ektachrome Video News Film 7250; and (c) one roll of Fujicolor Reversal Film RT500, type 8428.

Once the film was developed, a Vanguard Motion Analyzer was used to project the film's images onto a viewing table. The X and Y coordinates of the 21 segmental endpoints were then digitized with the use of a Numonics electronic digitizer, model 1224. An Apple II Plus computer which was interfaced with the Numonics unit was used to store these coordinates in a disk file. Several computer programs were then run in order to obtain print-outs of the raw data, the center of gravity values, and the velocity and acceleration data.

## Filming Procedures

The data collection procedures were carried out in Buffalo, New York from August 18, 1984 to August 20, 1984. Six subjects were filmed on each of these three days. The actual filming took place at a track which was located near Houghton Park, site of the Women's National Fast-Pitch Softball Tournament.

Prior to the filming, each subject was asked to complete a questionnaire and sign a consent form. The investigator recorded the subject's height and weight and obtained other essential data such as the weight of the softball, the width of the subject's pelvic and shoulder girdles, and measurements of the subject's feet. After photographs were taken of the manner in which the subject gripped the drop ball and rise ball, the individual was allowed adequate time to warm up properly.

During the filming, the subjects were instructed to perform three trials of three different types of pitches. Specifically, the pitch selection included fast balls, drop balls, and rise balls. Upon completion of each set of pitches, the subjects were asked to determine which one of the three trials represented their best effort. Thus, only one trial of each type of pitch was considered for analysis.

## Data Analysis Procedures

Based upon the literature review, the investigator identified 12 variables associated with a successful windmill style softball pitch. These variables included: (a) the velocity of the pitch at release; (b) the maximum degree of hip rotation; (c) the maximum degree of shoulder rotation; (d) the angle of the trail foot during the weight shift; (e) the angle of the lead foot at foot plant; (f) the degree of trunk inclination during the weight shift; (g) the degree of trunk inclination at release; (h) the degree of hip closure at release; (i) the degree of shoulder closure at release; (j) the stride length; (k) the torque about the shoulder during the arm's downswing; and (l) the torque about the wrist at release. Each of these variables is described in this section.

The Velocity of the Pitch at Release

The velocity of the pitch was determined to be equivalent to the linear velocity of the softball at release. A computer program designed to calculate velocity and acceleration data was used in order to obtain the value of this variable.

The Maximum Degree of Hip Rotation

Hip rotation was defined as the maximum degree to which the subject's hips were turned during the execution of a pitch. This variable was determined by analyzing the film produced by the sagittal camera, and it was mathematically calculated by the equation,

$$\sin \theta = \frac{\sqrt{(X_2 - X_1)^2 + (Y_2 - Y_1)^2}}{Z} \qquad (1)$$

where $\theta$ was the maximum degree of hip rotation, $X_1$ and $Y_1$ represented the coordinates of the right greater trochanter, $X_2$ and $Y_2$ represented the coordinates of the left greater trochanter, and Z was the width of the subject's pelvic girdle.

## The Maximum Degree of Shoulder Rotation

Shoulder rotation was defined as the maximum degree to which the subject's shoulders were turned during the execution of a pitch. This variable, like hip rotation, was determined by analyzing the film produced by the sagittal camera, and it was calculated by using Equation 1 where $\theta$ was the maximum degree of shoulder rotation, $X_1$ and $Y_1$ represented the coordinates of the right coracoid process, $X_2$ and $Y_2$ represented the coordinates of the left coracoid process, and Z was the width of the subject's shoulder girdle.

## The Angle of the Trail Foot During the Weight Shift

The trail foot was defined as the foot the subject used in order to push off of the pitcher's rubber. Therefore, the right foot was considered to be the trail foot in the case of a right-handed pitcher while the left foot was the trail foot in the case of a left-hander. The angle of the trail foot during the weight shift was determined by analyzing the film produced by the frontal camera, and this angle was mathematically calculated by the equation,

$$\sin \theta = \frac{\sqrt{(X_2 - X_1)^2}}{Z} \qquad (2)$$

where $\theta$ was the angle of the trail foot, $X_1$ represented the X coordinate of the end of the trail foot, $X_2$ represented the X coordinate of the medial malleolus, and Z was the distance from the front of the heel to the end of the foot.

## The Angle of the Lead Foot at Foot Plant

The lead foot was defined as the foot the subject moved towards home plate during the execution of a pitch. Therefore, the left foot was considered to be the lead foot in the case of a right-handed pitcher while the right foot was the lead foot in the case of a left-hander. The angle of the lead foot at foot plant was determined by analyzing the film produced by the frontal camera, and this angle was calculated by using Equation 2 where $\theta$ was the angle of the lead foot, $X_1$ represented the X coordinate of the end of the lead foot, $X_2$ represented the X coordinate of the medial malleolus, and Z was the distance from the front of the heel to the end of the foot.

The Degree of Trunk Inclination During the Weight Shift

Trunk inclination during the weight shift was defined as the degree to which the subject was bent over as all of the weight was placed on the trail foot at the beginning of the pitching motion. The value of this variable was determined by analyzing the film produced by the sagittal camera. In the case of a right-handed pitcher, the degree of trunk inclination during the weight shift was mathematically calculated by the equation,

$$\tan \theta = \frac{X_2 - X_1}{Y_2 - Y_1} \quad (3)$$

where $\theta$ was the degree of trunk inclination, $X_1$ and $Y_1$ represented the coordinates of the subject's crotch, and $X_2$ and $Y_2$ represented the coordinates of the subject's sternum. In the case of a left-hander, the value of this variable was calculated by the equation,

$$\tan \theta = \frac{X_1 - X_2}{Y_2 - Y_1} \quad (4)$$

Since trunk inclination could be thought of as the amount the trunk segment deviated from the vertical, the larger the obtained value of $\theta$, the more the subject was bent over as the weight was placed on the trail foot. A negative value would indicate that the subject was leaning backwards.

## The Degree of Trunk Inclination at Release

Trunk inclination at release was defined as the degree to which the subject was bent over as the pitch was released. The value of this variable was determined by analyzing the film produced by the sagittal camera. In the case of a right-handed pitcher, the degree of trunk inclination at release was mathematically calculated by using Equation 3 while Equation 4 was utilized when calculating the value of this variable in the case of a left-hander.

## The Degree of Hip Closure at Release

Hip closure was defined as the degree to which the subject's hips were facing home plate at the end of the delivery. This variable was determined by analyzing the film produced by the frontal camera, and it was mathematically calculated by the equation,

$$\cos \theta = \frac{\sqrt{(X_2 - X_1)^2 + (Y_2 - Y_1)^2}}{Z} \qquad (5)$$

where $\theta$ was the degree of hip closure, $X_1$ and $Y_1$ represented the coordinates of the right greater trochanter, $X_2$ and $Y_2$ represented the coordinates of the left greater trochanter, and Z was the width of the subject's pelvic girdle. The smaller the obtained value of $\theta$, the more nearly the pitcher's hips were parallel with the front edge of home plate as the pitch was released.

## The Degree of Shoulder Closure at Release

Shoulder closure was defined as the degree to which the subject's shoulders were facing home plate at the end of the delivery. This variable, like hip closure, was determined by analyzing the film produced by the frontal camera, and it was calculated by using Equation 5 where $\theta$ was the degree of shoulder closure, $X_1$ and $Y_1$ represented the coordinates of the right coracoid process, $X_2$ and $Y_2$ represented the coordinates of the left coracoid process, and Z was the width of the subject's shoulder girdle. The smaller the obtained value of $\theta$, the more nearly the pitcher's shoulders were parallel with the front edge of home plate as the pitch was released.

## The Stride Length

Stride length was calculated by the equation,

$$A = X_1 - X_2 \qquad (6)$$

where A was the length of the subject's stride in feet, $X_1$ represented the X coordinate of the right medial malleolus at foot plant, and $X_2$ represented the X coordinate of the left medial malleolus.

The obtained stride length was then compared to the subject's standing height by the equation,

$$P = \frac{A}{B} \times 100\% \qquad (7)$$

where P was the percentage obtained when the subject's stride length was compared to the standing height, A represented the stride length in feet, and B represented the subject's height in feet.

## The Torque About the Shoulder During the Arm's Downswing

Torque about the shoulder was determined by analyzing the film produced by the sagittal camera, and it was mathematically calculated by the equation,

$$T = (m_1r_1^2 + m_2r_2^2 + m_3r_3^2 + m_4r_4^2)\alpha \quad (8)$$

where T was the torque about the shoulder; $m_1$, $m_2$, $m_3$, and $m_4$ represented the masses of the arm, forearm, hand, and softball respectively; $r_1$, $r_2$, $r_3$, and $r_4$ represented the radii of the arm, forearm, hand, and softball respectively; and $\alpha$ was the angular acceleration.

The masses of the arm, forearm, and hand were calculated by the equation,

$$m = \frac{W_s \times p}{32.2 \text{ ft/sec}^2} \quad (9)$$

where m was the mass of the given body part, $W_s$ was the weight of the subject, and p represented the proportion of the subject's weight included in each body part. These proportions may be found by referring to Kreighbaum et al. (1981).

The mass of the softball was calculated by the equation,

$$m = \frac{W_b}{32.2 \text{ ft/sec}^2} \quad (10)$$

where m was the mass of the softball and $W_b$ was the weight of the softball.

The radii, $r_1$, $r_2$, $r_3$, and $r_4$, were determined by calculating the distances between the shoulder joint and the centers of gravity of the arm, forearm, hand, and softball respectively.

Finally, angular acceleration was calculated by finding the difference between two consecutive angular velocities and dividing this difference by time.

The Torque About the Wrist at Release

Torque about the wrist was determined by analyzing the film produced by the sagittal camera, and it was calculated by the equation,

$$T = (m_1 r_1^2 + m_2 r_2^2)\alpha \tag{11}$$

where T was the torque about the wrist, $m_1$ and $m_2$ represented the masses of the hand and the softball respectively, $r_1$ and $r_2$ represented the radii of the hand and the softball respectively, and $\alpha$ was the angular acceleration.

The mass of the hand was calculated by using Equation 9 where m was the mass of the hand, $W_s$ was the weight of the subject, and p represented the proportion of the subject's weight included in the hand.

The radii, $r_1$ and $r_2$, were determined by calculating the distances between the wrist joint and the centers of gravity of the hand and the softball respectively.

Statistical Analysis Procedures

Since all of the subjects were considered to have a good fast ball, the investigator used each subject's fast ball data in calculating the values of the 12 variables previously described. In the case of the drop ball and rise ball, the investigator found it necessary to divide the subjects into the following four groups based upon their responses to the questionnaire: (a) those pitchers who threw rise balls over 70% of the time during a game; (b) those pitchers who threw drop balls over 70% of the time during a game; (c) those pitchers who threw the drop ball and rise ball an approximately equal number of times; and (d) those pitchers who were not included in the other three categories. Once the groups were defined, only the drop ball and rise ball data collected from members of the first three groups were used in calculating the values of the 12 variables. It was hoped, then, that the mechanics of the good rise ball pitchers could be compared with the mechanics of those pitchers who seldom used the rise. Similarly, the mechanics of the good drop ball pitchers could be compared with the mechanics of those pitchers who rarely used the drop.

Once the values of the 12 variables were found for each of the previously mentioned situations, the investigator calculated the mean and standard deviation for all of the variables. Pearson product-moment correlation coefficients were also calculated in order to determine if any significant relationships existed among the variables.

# CHAPTER IV

# ANALYSIS OF DATA AND DISCUSSION OF RESULTS

The problem of the study was to identify the specific kinematic and kinetic variables associated with a successful windmill style softball pitch. The results of the investigation were grouped under the following headings: (a) a descriptive analysis of the fast ball; (b) the relationship between selected variables; (c) a comparison of the drop ball and rise ball deliveries; (d) a descriptive analysis of the drop ball; (e) a descriptive analysis of the rise ball; and (f) summary.

## A Descriptive Analysis of the Fast Ball

Table 1 displays the values obtained for each of the subjects on the 12 variables associated with a windmill style softball pitch. The mean and standard deviation for each variable are also shown in this table. The interpretation of these values is discussed in this section.

Table 1

Fast Ball Data

| Subject | Variable | |
|---|---|---|
| | Velocity | Hip Rotation |
| 1 | 87.63 ft/sec | 62.38 degrees |
| 2 | 82.12 ft/sec | 57.65 degrees |
| 3 | 78.06 ft/sec | 68.71 degrees |
| 4 | 85.83 ft/sec | 33.17 degrees |
| 5 | 81.12 ft/sec | 68.25 degrees |
| 6 | 99.18 ft/sec | 60.87 degrees |
| 7 | 78.92 ft/sec | 40.24 degrees |
| 8 | 87.46 ft/sec | 58.23 degrees |
| 9 | 90.31 ft/sec | 77.53 degrees |
| 10 | 96.57 ft/sec | 60.52 degrees |
| 11 | 93.97 ft/sec | 56.15 degrees |
| 12 | 89.12 ft/sec | 56.20 degrees |
| 13 | 81.50 ft/sec | 56.07 degrees |
| 14 | 76.63 ft/sec | 52.23 degrees |
| 15 | 83.17 ft/sec | 63.15 degrees |
| 16 | 81.35 ft/sec | 47.73 degrees |
| Mean | 85.81 ft/sec | 57.44 degrees |
| Standard Deviation | 6.69 ft/sec | 10.80 degrees |

Table 1 - Continued

| Subject | Variable | |
| --- | --- | --- |
| | Shoulder Rotation | Trail Foot Angle |
| 1 | 59.09 degrees | 7.61 degrees |
| 2 | 88.65 degrees | 10.64 degrees |
| 3 | 61.22 degrees | 10.37 degrees |
| 4 | 54.80 degrees | 15.36 degrees |
| 5 | 62.47 degrees | 32.96 degrees |
| 6 | 63.74 degrees | 19.27 degrees |
| 7 | 69.75 degrees | 42.74 degrees |
| 8 | 55.03 degrees | 23.41 degrees |
| 9 | 59.54 degrees | 7.76 degrees |
| 10 | 67.27 degrees | 6.22 degrees |
| 11 | 64.60 degrees | 23.74 degrees |
| 12 | 68.73 degrees | 32.68 degrees |
| 13 | 78.02 degrees | 9.21 degrees |
| 14 | 57.71 degrees | 12.43 degrees |
| 15 | 68.89 degrees | 12.94 degrees |
| 16 | 89.92 degrees | 12.12 degrees |
| Mean | 66.84 degrees | 17.47 degrees |
| Standard Deviation | 10.60 degrees | 10.80 degrees |

Table 1 - Continued

| Subject | Variable: Lead Foot Angle | Variable: Trunk Inclination/ Weight Shift |
|---|---|---|
| 1 | 83.27 degrees | 33.80 degrees |
| 2 | 14.98 degrees | 42.86 degrees |
| 3 | 36.87 degrees | 20.15 degrees |
| 4 | 25.49 degrees | 33.58 degrees |
| 5 | 29.74 degrees | 32.87 degrees |
| 6 | 25.59 degrees | 38.72 degrees |
| 7 | 27.61 degrees | 41.22 degrees |
| 8 | 15.36 degrees | 45.00 degrees |
| 9 | 54.10 degrees | 21.09 degrees |
| 10 | 58.39 degrees | 37.18 degrees |
| 11 | 40.57 degrees | 23.59 degrees |
| 12 | 30.66 degrees | 40.52 degrees |
| 13 | 48.76 degrees | 55.13 degrees |
| 14 | 52.61 degrees | 43.30 degrees |
| 15 | 53.13 degrees | 21.31 degrees |
| 16 | 15.66 degrees | 40.74 degrees |
| Mean | 38.30 degrees | 35.69 degrees |
| Standard Deviation | 18.90 degrees | 9.96 degrees |

Table 1 - Continued

| Subject | Variable: Trunk Inclination/ Release | Variable: Hip Closure |
|---|---|---|
| 1 | 27.44 degrees | 28.83 degrees |
| 2 | 5.12 degrees | 32.11 degrees |
| 3 | 0.00 degrees | 24.55 degrees |
| 4 | 11.38 degrees | 0.00 degrees |
| 5 | 0.78 degrees | 23.13 degrees |
| 6 | -3.30 degrees | 24.70 degrees |
| 7 | 3.48 degrees | 0.00 degrees |
| 8 | -4.40 degrees | 28.01 degrees |
| 9 | 7.18 degrees | 44.36 degrees |
| 10 | 14.72 degrees | 40.95 degrees |
| 11 | -14.98 degrees | 22.40 degrees |
| 12 | 24.64 degrees | 31.09 degrees |
| 13 | -7.65 degrees | 12.65 degrees |
| 14 | 1.23 degrees | 30.93 degrees |
| 15 | 11.23 degrees | 33.09 degrees |
| 16 | 6.05 degrees | 23.37 degrees |
| Mean | 5.18 degrees | 25.01 degrees |
| Standard Deviation | 11.10 degrees | 12.30 degrees |

Table 1 - Continued

| Subject | Variable | |
|---|---|---|
| | Shoulder Closure | Stride Length |
| 1 | 22.41 degrees | 55.22% |
| 2 | 27.42 degrees | 70.34% |
| 3 | 29.01 degrees | 57.86% |
| 4 | 0.00 degrees | 55.89% |
| 5 | 13.94 degrees | 64.51% |
| 6 | 28.13 degrees | 63.33% |
| 7 | 0.00 degrees | 62.35% |
| 8 | 26.36 degrees | 58.04% |
| 9 | 32.63 degrees | 54.63% |
| 10 | 34.09 degrees | 56.27% |
| 11 | 19.60 degrees | 57.09% |
| 12 | 18.90 degrees | 71.66% |
| 13 | 17.65 degrees | 56.09% |
| 14 | 22.91 degrees | 61.28% |
| 15 | 29.90 degrees | 59.39% |
| 16 | 19.38 degrees | 54.02% |
| Mean | 21.40 degrees | 59.87% |
| Standard Deviation | 10.10 degrees | 5.37% |

Table 1 - Continued

| Subject | Variable | |
|---|---|---|
| | Shoulder Torque | Wrist Torque |
| 1 | -2399.66 lb-ft | -62.03 lb-ft |
| 2 | 0.00 lb-ft | -472.32 lb-ft |
| 3 | 3577.52 lb-ft | 825.04 lb-ft |
| 4 | -5324.92 lb-ft | -2543.88 lb-ft |
| 5 | -7313.61 lb-ft | 1595.55 lb-ft |
| 6 | 13041.99 lb-ft | -996.54 lb-ft |
| 7 | 4249.86 lb-ft | 1195.52 lb-ft |
| 8 | 0.00 lb-ft | 0.00 lb-ft |
| 9 | 3388.30 lb-ft | 471.84 lb-ft |
| 10 | 3316.81 lb-ft | -68.04 lb-ft |
| 11 | 4652.59 lb-ft | -1886.91 lb-ft |
| 12 | 10379.80 lb-ft | -2482.48 lb-ft |
| 13 | 1318.02 lb-ft | -806.61 lb-ft |
| 14 | 0.00 lb-ft | 0.00 lb-ft |
| 15 | -5011.38 lb-ft | -854.23 lb-ft |
| 16 | -3280.14 lb-ft | -472.94 lb-ft |
| Mean | 1287.20 lb-ft | -409.88 lb-ft |
| Standard Deviation | 5486.00 lb-ft | 1189.00 lb-ft |

## The Velocity of the Pitch at Release

The mean for the velocity of the pitch at release was 85.81 ft/sec while the standard deviation was calculated to be 6.69 ft/sec. These results indicate that the subjects were quite highly skilled and fairly equal with respect to windmill pitching velocity. In fact, the table shows that 9 of the 16 subjects had pitching speeds in the range of 80 to 90 ft/sec and that only Subject 6 had a velocity well outside this range.

## The Maximum Degree of Hip Rotation

The mean for hip rotation was 57.44 degrees while the standard deviation was computed to be 10.80 degrees. The mean value for this variable indicates that the subjects did not tend to completely turn their hips during the execution of a pitch. In fact, Subject 4 only rotated her hips 33.17 degrees. The rather large value associated with the standard deviation suggests that there was a great deal of variability between the subjects with respect to hip rotation. This can be demonstrated by comparing 33.17 degrees, the hip rotation value of Subject 4, with the value obtained for Subject 9, 77.53 degrees.

## The Maximum Degree of Shoulder Rotation

The mean for shoulder rotation was 66.84 degrees while the standard deviation was calculated to be 10.60 degrees. The mean value for this variable indicates that the subjects tended to turn their shoulders to a greater extent than their hips. In fact, only five of the subjects had a larger value for their hip rotation than for their shoulder rotation. The rather large value associated with the standard deviation suggests that there was a great deal of variability between the subjects with respect to shoulder rotation. This can be demonstrated by comparing 54.80 degrees, the shoulder rotation value of Subject 4, with the value obtained for Subject 16, 89.92 degrees.

## The Angle of the Trail Foot During the Weight Shift

The mean for the angle of the trail foot during the weight shift was 17.47 degrees while the standard deviation was computed to be 10.80 degrees. The mean value indicates that the subjects did not tend to have their trail foot turned to any great extent as the weight shift occurred. In fact, most of the subjects turned this foot well after the lead foot had begun its movement towards home plate. The rather large value associated with the standard deviation suggests that there was a great deal of variability between the subjects with respect to the angle of the trail foot during the weight shift. Subject 7, with a value of 42.74 degrees for this variable, tended to turn her foot as she started her delivery while Subject 10, with a value of 6.22 degrees, did not turn her trail foot much until she was well into her motion.

## The Angle of the Lead Foot at Foot Plant

The mean for the angle of the lead foot at foot plant was 38.30 degrees while the standard deviation was calculated to be 18.90 degrees. The mean value indicates that the subjects tended to have their lead foot turned in the direction of the throwing arm side as it was planted. The rather large value associated with the standard deviation suggests that there was a great deal of variability between the subjects with respect to the angle of the lead foot at foot plant. After all, Subject 1 planted her lead foot at an angle of 83.27 degrees while the lead foot of Subject 2, Subject 8, and Subject 16 was nearly pointed at home plate as it was planted.

## The Degree of Trunk Inclination During the Weight Shift

The mean for the degree of trunk inclination during the weight shift was 35.69 degrees while the standard deviation was computed to be 9.96 degrees. The mean value indicates that the subjects tended to lean over as they started their pitching motion. The rather large value associated with the standard deviation suggests that there was a great deal of variability between the subjects with respect to the degree of trunk inclination during the weight shift. In fact, the values for this variable ranged from 20.15 degrees, the trunk inclination value of Subject 3, to the value obtained for Subject 13, 55.13 degrees.

## The Degree of Trunk Inclination at Release

The mean for the degree of trunk inclination at release was 5.18 degrees while the standard deviation was calculated to be 11.10 degrees. The mean value indicates that the subjects tended to be nearly upright as they released the softball. The rather large value associated with the standard deviation suggests that there was a great deal of variability between the subjects with respect to the degree of trunk inclination at release. In fact, Table 1 shows that Subject 1 and Subject 12 were bent over quite a bit as they delivered the pitch while four of the subjects were leaning backwards at release.

## The Degree of Hip Closure at Release

The mean for hip closure was 25.01 degrees while the standard deviation was computed to be 12.30 degrees. The mean value for this variable indicates that the subjects did not tend to have their hips completely facing home plate as the softball was released. In fact, Subject 9 still had her hips turned at a 44.36 degree angle. The rather large value associated with the standard deviation suggests that there was a great deal of variability between the subjects with respect to hip closure. This can be demonstrated by comparing 44.36 degrees, the hip closure value of Subject 9, with the value of 0.00 degrees obtained for Subjects 4 and 7.

## The Degree of Shoulder Closure at Release

The mean for shoulder closure was 21.40 degrees while the standard deviation was calculated to be 10.10 degrees. The mean value for this variable indicates that the subjects tended to have their shoulders more nearly parallel with the front edge of home plate at release than they did their hips. In fact, only three of the subjects had a smaller value for their hip closure than for their shoulder closure. The rather large value associated with the standard deviation suggests that there was a great deal of variability between the subjects with respect to shoulder closure. This can be demonstrated by comparing 34.09 degrees, the shoulder closure value of Subject 10, with the value of 0.00 degrees obtained for Subjects 4 and 7.

## The Stride Length

The mean for stride length was 59.87% of the subject's standing height while the standard deviation was computed to be 5.37%. The mean value for this variable indicates that the subjects tended to use a stride which was slightly over one-half of their standing height. In fact, none of the subjects had a stride length value of less than 50%. The rather small value associated with the standard deviation suggests that the group of subjects was fairly homogeneous with respect to this variable.

## The Torque About the Shoulder During the Arm's Downswing

The mean for the torque about the shoulder was 1287.20 lb-ft while the standard deviation was calculated to be 5486.00 lb-ft. These results indicate that the group of subjects was extremely heterogeneous with respect to the amount of torque about the shoulder during the arm's downswing. Eight of the subjects had positive torques suggesting that the arm was accelerating as it began its downward motion while five of the subjects had negative torque values. The subjects with the negative torques were those who had their elbow flexed to a greater extent during the windmill pitching motion. It appears that this negative torque was a result of an angular deceleration of the arm about the shoulder which allowed the subject time to fully extend her elbow in preparation for the softball's release.

The Torque About the Wrist at Release

The mean for the torque about the wrist was -409.88 lb-ft while the standard deviation was computed to be 1189.00 lb-ft. These results indicate that the group of subjects was extremely heterogeneous with respect to the amount of torque about the wrist at release. Four of the subjects had positive torques suggesting that the hand was still accelerating about the wrist as the softball was released while 10 of the subjects had negative torque values. The subjects with the negative torques were those who had already completed their wrist snap prior to the release of the softball. Consequently, there was an angular deceleration of the hand about the wrist.

## Discussion of the Fast Ball Results

Based upon the values presented in Table 1, the investigator discovered that the group of subjects was fairly homogeneous with respect to two variables, the velocity of the pitch at release and the stride length, and extremely heterogeneous with respect to the other 10 variables. This suggests that different pitchers are able to use slightly different mechanics and still throw a good fast ball. In other words, it appears that the proper combination of pitching mechanics is required in order to successfully throw this pitch.

In addition, the fast ball data found in Table 1 prompted the investigator to make the following conclusions:

1. A large amount of hip and shoulder rotation is not necessary in order to throw a successful fast ball. After all, the subjects in this study did not tend to completely turn their hips and shoulders during the execution of a pitch, yet each subject was considered to be a good fast ball pitcher.

2. It does not matter whether the pitcher turns the trail foot towards the throwing arm side as the pitching motion begins or as the lead foot is moving towards home plate later in the delivery.

3. It does not matter whether the lead foot is turned in the direction of the throwing arm side at foot plant or is nearly pointed at home plate.

4. Some degree of trunk inclination is necessary at the beginning of the pitching motion. It appears that this body lean aids the pitcher in moving the lead foot towards home plate.

5. It does not matter whether the pitcher is bent forward or is leaning backwards as the softball is released as long as this degree of trunk inclination is not too large.

6. A large amount of hip and shoulder closure is not necessary in order to throw a successful fast ball. After all, the subjects in this study did not tend to have their hips and shoulders completely facing home plate as they delivered the pitch.

7. Pitchers should use a stride which is slightly greater than one-half of their standing height.

## The Relationship Between Selected Variables

Table 2 displays the Pearson product-moment correlation coefficients which were calculated for the 12 variables associated with a fast ball using the windmill style softball delivery. From this table, the following results are apparent:

Table 2

Correlation Matrix for the Selected Variables

| Variable | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 1. Velocity | 1.0000 | | | | | |
| 2. Hip Rotation | 0.2095 | 1.0000 | | | | |
| 3. Shoulder Rotation | -0.2106 | -0.1439 | 1.0000 | | | |
| 4. Trail Foot Angle | -0.0888 | -0.3029 | -0.1018 | 1.0000 | | |
| 5. Lead Foot Angle | 0.1320 | 0.3742 | -0.3347 | -0.4549 | 1.0000 | |
| 6. Trunk Inclination/ Weight Shift | -0.1492 | -0.4453 | 0.3595 | 0.1258 | -0.2725 | 1.0000 |
| 7. Trunk Inclination/ Release | 0.0606 | -0.0102 | -0.0391 | -0.1347 | 0.3882 | -0.0761 |
| 8. Hip Closure | 0.3316 | 0.7651 | -0.0003 | -0.4632 | 0.3538 | -0.2837 |
| 9. Shoulder Closure | 0.3496 | 0.7746 | 0.0417 | -0.5998 | 0.3015 | -0.2599 |
| 10. Stride Length | -0.0789 | -0.0051 | 0.2284 | 0.5035 | -0.4025 | 0.2418 |
| 11. Shoulder Torque | 0.5316 | 0.1254 | -0.0215 | 0.1950 | -0.0823 | 0.0905 |
| 12. Wrist Torque | -0.4043 | 0.4142 | -0.0520 | 0.0836 | 0.1073 | -0.0763 |

Table 2 - Continued

| Variable | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|
| 1. Velocity | | | | | | |
| 2. Hip Rotation | | | | | | |
| 3. Shoulder Rotation | | | | | | |
| 4. Trail Foot Angle | | | | | | |
| 5. Lead Foot Angle | | | | | | |
| 6. Trunk Inclination/ Weight Shift | | | | | | |
| 7. Trunk Inclination/ Release | 1.0000 | | | | | |
| 8. Hip Closure | 0.2455 | 1.0000 | | | | |
| 9. Shoulder Closure | 0.0224 | 0.9035 | 1.0000 | | | |
| 10. Stride Length | 0.1353 | 0.0614 | -0.0619 | 1.0000 | | |
| 11. Shoulder Torque | -0.1031 | 0.1424 | 0.2351 | 0.3242 | 1.0000 | |
| 12. Wrist Torque | -0.1375 | 0.1316 | 0.1353 | -0.0969 | -0.2340 | 1.0000 |

1. There was a very high positive relationship between hip closure and shoulder closure. In other words, the more nearly the subject's hips were facing home plate at release, the more nearly the shoulders were also facing in that direction.

2. There was a moderate positive relationship between hip rotation and hip closure. Thus, the less the subjects turned their hips at the beginning of the pitch, the more likely they were to have them facing in the direction of home plate at release.

3. There was a moderate positive relationship between hip rotation and shoulder closure. Thus, the less the subjects turned their hips at the beginning of the pitch, the more likely they were to have their shoulders facing in the direction of home plate at release.

There were no high relationships between the velocity of the fast ball at release and any of the other variables, although there was some positive relationship between velocity and the amount of torque about the shoulder during the arm's downswing. In other words, those subjects who had the larger torque values tended to throw the faster pitches. There was also some negative relationship between velocity and the amount of torque about the wrist at release. This indicates that the faster pitchers tended to complete their wrist snap prior to releasing the softball. Because of the fact that there were no high relationships between the velocity of the pitch at release and any of the other variables, the investigator concluded that a combination of proper pitching mechanics is necessary in order to throw a good fast ball. In other words, there is no one variable which seems to be the primary reason that a pitcher can throw the ball hard.

A bit surprising was the fact that there was little or no relationship between hip rotation and any of the three variables, shoulder rotation, the angle of the trail foot during the weight shift, or the angle of the lead foot at foot plant. It seems that a large hip rotation value would be associated with a large shoulder rotation value and that greater hip rotation would occur if the trail foot was rotated outward during the weight shift or if the lead foot was turned in the direction of the throwing arm side at foot plant.

Also surprising was the fact that there was little or no relationship between shoulder rotation and shoulder closure. After all, it seems logical that there should be a moderately high positive relationship between the two variables. In other words, the less the subjects turn their shoulders at the beginning of the pitch, the more likely they should be to have them facing in the direction of home plate at release.

## A Comparison of the Drop Ball and Rise Ball Deliveries

Table 3 displays the values obtained for Subject 6, Subject 7, and Subject 8 on the 12 variables associated with a drop ball and rise ball using the windmill style softball delivery. The pitching mechanics used by Subjects 6, 7, and 8 were analyzed in this section, because these three subjects were the pitchers who threw the drop ball and rise ball an approximately equal number of times during a game. Therefore, the investigator made the assumption that the subjects could throw both types of pitches with equal effectiveness. The mean and standard deviation for each variable are also shown in this table. The interpretation of these values is discussed in this section.

### The Velocity of the Pitch at Release

The mean value for the drop ball was 87.05 ft/sec while the standard deviation was 9.35 ft/sec. For the rise ball, the mean value was 84.10 ft/sec while the standard deviation was calculated to be 8.54 ft/sec. These results indicate that the subjects tended to throw the drop ball faster than the rise.

Table 3

Differences Between the Drop Ball and Rise Ball

| Subject | Velocity | | Hip Rotation | |
|---|---|---|---|---|
| | Drop | Rise | Drop | Rise |
| 6 | 97.51 ft/sec | 93.59 ft/sec | 61.98 degrees | 64.74 degrees |
| 7 | 79.51 ft/sec | 77.03 ft/sec | 40.18 degrees | 45.49 degrees |
| 8 | 84.12 ft/sec | 81.68 ft/sec | 56.91 degrees | 66.07 degrees |
| Mean | 87.05 ft/sec | 84.10 ft/sec | 53.02 degrees | 58.77 degrees |
| Standard Deviation | 9.35 ft/sec | 8.54 ft/sec | 11.40 degrees | 11.50 degrees |

Table 3 - Continued

| Subject | Shoulder Rotation | | Trail Foot Angle | |
|---|---|---|---|---|
| | Drop | Rise | Drop | Rise |
| 6 | 61.33 degrees | 72.73 degrees | 20.18 degrees | 24.83 degrees |
| 7 | 59.95 degrees | 65.24 degrees | 34.25 degrees | 37.76 degrees |
| 8 | 52.99 degrees | 60.35 degrees | 25.49 degrees | 40.20 degrees |
| Mean | 58.09 degrees | 66.11 degrees | 26.64 degrees | 34.26 degrees |
| Standard Deviation | 4.47 degrees | 6.24 degrees | 7.11 degrees | 8.26 degrees |

Table 3 - Continued

| Subject | Lead Foot Angle | | Trunk Inclination/ Weight Shift | |
|---|---|---|---|---|
| | Drop | Rise | Drop | Rise |
| 6 | 24.58 degrees | 28.69 degrees | 36.35 degrees | 41.08 degrees |
| 7 | 12.43 degrees | 15.36 degrees | 41.60 degrees | 45.56 degrees |
| 8 | 30.87 degrees | 20.34 degrees | 43.68 degrees | 40.56 degrees |
| Mean | 22.63 degrees | 21.46 degrees | 40.54 degrees | 42.40 degrees |
| Standard Deviation | 9.37 degrees | 6.74 degrees | 3.78 degrees | 2.75 degrees |

Table 3 - Continued

| Subject | Trunk Inclination/ Release | | Hip Closure | |
|---|---|---|---|---|
| | Drop | Rise | Drop | Rise |
| 6 | 5.30 degrees | -5.09 degrees | 25.99 degrees | 29.43 degrees |
| 7 | 4.50 degrees | -5.71 degrees | 0.00 degrees | 0.00 degrees |
| 8 | -1.96 degrees | -10.75 degrees | 26.00 degrees | 29.55 degrees |
| Mean | 2.61 degrees | -7.18 degrees | 17.33 degrees | 19.66 degrees |
| Standard Deviation | 3.98 degrees | 3.10 degrees | 15.00 degrees | 17.00 degrees |

Table 3 - Continued

| Subject | Shoulder Closure | | Stride Length | |
|---|---|---|---|---|
| | Drop | Rise | Drop | Rise |
| 6 | 26.98 degrees | 31.92 degrees | 61.47% | 66.19% |
| 7 | 0.00 degrees | 0.00 degrees | 54.91% | 61.46% |
| 8 | 25.76 degrees | 32.89 degrees | 53.48% | 60.78% |
| Mean | 17.58 degrees | 21.60 degrees | 56.62% | 62.81% |
| Standard Deviation | 15.20 degrees | 18.70 degrees | 4.26% | 2.95% |

Table 3 - Continued

| Subject | Shoulder Torque | | Wrist Torque | |
|---|---|---|---|---|
| | Drop | Rise | Drop | Rise |
| 6 | 3973.20 lb-ft | -8059.05 lb-ft | -737.89 lb-ft | 620.77 lb-ft |
| 7 | 1420.89 lb-ft | -9475.18 lb-ft | -1171.43 lb-ft | -451.92 lb-ft |
| 8 | -3562.14 lb-ft | -3336.27 lb-ft | -884.22 lb-ft | 247.98 lb-ft |
| Mean | 610.65 lb-ft | -6956.83 lb-ft | -931.18 lb-ft | 138.94 lb-ft |
| Standard Deviation | 3832.00 lb-ft | 3214.00 lb-ft | 221.00 lb-ft | 545.00 lb-ft |

## The Maximum Degree of Hip Rotation

The mean value for the drop ball was 53.02 degrees while the standard deviation was 11.40 degrees. For the rise ball, the mean value was 58.77 degrees while the standard deviation was computed to be 11.50 degrees. In other words, the subjects tended to turn their hips more when throwing a rise ball than they did when pitching a drop.

## The Maximum Degree of Shoulder Rotation

The mean value for the drop ball was 58.09 degrees while the standard deviation was 4.47 degrees. For the rise ball, the mean value was 66.11 degrees while the standard deviation was calculated to be 6.24 degrees. In other words, the subjects tended to turn their shoulders more when throwing a rise ball than they did when pitching a drop.

## The Angle of the Trail Foot During the Weight Shift

The mean value for the drop ball was 26.64 degrees while the standard deviation was 7.11 degrees. For the rise ball, the mean value was 34.26 degrees while the standard deviation was computed to be 8.26 degrees. These results indicate that the subjects tended to have their trail foot turned to a greater extent during the weight shift when pitching a rise ball than they did when throwing a drop.

## The Angle of the Lead Foot at Foot Plant

The mean value for the drop ball was 22.63 degrees while the standard deviation was 9.37 degrees. For the rise ball, the mean value was 21.46 degrees while the standard deviation was calculated to be 6.74 degrees. These results indicate that the subjects tended to have their lead foot turned to the same extent at foot plant no matter which pitch they threw. From Table 3, it can be seen that Subject 6 and Subject 7 turned their lead foot to a greater extent when pitching the rise ball while Subject 8 turned her foot more when throwing the drop.

## The Degree of Trunk Inclination During the Weight Shift

The mean value for the drop ball was 40.54 degrees while the standard deviation was 3.78 degrees. For the rise ball, the mean value was 42.40 degrees while the standard deviation was computed to be 2.75 degrees. These results indicate that the subjects tended to bend over to the same extent during the weight shift no matter which pitch they threw. From Table 3, it can be seen that Subject 6 and Subject 7 bent over to a greater extent when pitching the rise ball while Subject 8 leaned over more when throwing the drop.

## The Degree of Trunk Inclination at Release

The mean value for the drop ball was 2.61 degrees while the standard deviation was 3.98 degrees. For the rise ball, the mean value was -7.18 degrees while the standard deviation was calculated to be 3.10 degrees. These results indicate that the subjects tended to be bent over slightly as they released the drop ball and leaning backwards as they let go of the rise. Although Subject 8 leaned backwards as she released both types of pitches, the angle of backward lean associated with the rise ball was much greater than that affiliated with the drop.

## The Degree of Hip Closure at Release

The mean value for the drop ball was 17.33 degrees while the standard deviation was 15.00 degrees. For the rise ball, the mean value was 19.66 degrees while the standard deviation was computed to be 17.00 degrees. In other words, the subjects tended to have their hips more nearly facing home plate at release when pitching a drop ball than they did when throwing a rise.

The Degree of Shoulder Closure at Release

The mean value for the drop ball was 17.58 degrees while the standard deviation was 15.20 degrees. For the rise ball, the mean value was 21.60 degrees while the standard deviation was calculated to be 18.70 degrees. In other words, the subjects tended to have their shoulders more nearly facing home plate at release when pitching a drop ball than they did when throwing a rise.

The Stride Length

The mean value for the drop ball was 56.62% while the standard deviation was 4.26%. For the rise ball, the mean value was 62.81% while the standard deviation was computed to be 2.95%. These results indicate that the subjects tended to take a shorter stride when throwing a drop ball than they did when pitching a rise.

The Torque About the Shoulder During the Arm's Downswing

The mean value for the drop ball was 610.65 lb-ft while the standard deviation was 3832.00 lb-ft. For the rise ball, the mean value was -6956.83 lb-ft while the standard deviation was calculated to be 3214.00 lb-ft. These results indicate that the subjects' arms tended to be accelerating as they began their downward motion during a drop ball delivery while there was an angular deceleration of the arm about the shoulder when the subjects were throwing a rise. This difference is probably the result of the unique arm motions associated with the two types of pitches.

## The Torque About the Wrist at Release

The mean value for the drop ball was -931.18 lb-ft while the standard deviation was 221.00 lb-ft. For the rise ball, the mean value was 138.94 lb-ft while the standard deviation was computed to be 545.00 lb-ft. These results indicate that the subjects' hands were still accelerating about the wrist as a rise ball was released while the subjects had already completed their wrist snap prior to the release of a drop.

## Discussion of the Drop Ball and Rise Ball Differences

Based upon the values presented in Table 3, the investigator made the following conclusions:

1. The drop ball is thrown with more initial velocity than the rise ball.

2. A large amount of hip and shoulder rotation is necessary when pitching a rise ball while a lesser degree is essential when throwing a drop.

3. It is necessary to turn the trail foot to a greater extent during the weight shift when throwing a rise ball.

4. The extent to which the lead foot is turned at foot plant can be the same when pitching a rise ball as it is when throwing a drop. Similarly, both the rise ball and drop ball can be effectively thrown with an approximately equal amount of trunk inclination during the weight shift.

5. The pitcher should be nearly upright when releasing a drop ball while a backwards lean is necessary for the delivery of a rise.

6. A large amount of hip and shoulder closure is necessary when pitching a drop ball while a lesser degree is essential when throwing a rise.

7. A short stride is necessary when pitching a drop ball while a longer stride is essential when throwing a rise.

8. The rise ball delivery is characterized by an angular deceleration of the arm about the shoulder during the arm's downswing while the drop ball motion is represented by an angular deceleration of the hand about the wrist at release.

# A Descriptive Analysis of the Drop Ball

Table 4 displays the mean and standard deviation calculated for the drop ball and rise ball pitchers on each of the 12 variables associated with a drop ball using the windmill style softball delivery. Subjects 1, 2, and 3 were considered to be the rise ball pitchers, because they were the subjects who claimed to throw rise balls over 70% of the time during a game. Subject 4 and Subject 5 were the drop ball pitchers, because each of them threw drop balls over 70% of the time. The interpretation of each mean and standard deviation is discussed in this section.

## The Velocity of the Pitch at Release

The mean value for the drop ball pitchers was 86.34 ft/sec while the standard deviation was 1.11 ft/sec. For the rise ball pitchers, the mean value was 77.09 ft/sec while the standard deviation was calculated to be 3.83 ft/sec. These results suggest that a good drop ball needs to be thrown with a great deal of velocity.

## The Maximum Degree of Hip Rotation

The mean value for the drop ball pitchers was 48.07 degrees while the standard deviation was 23.80 degrees.

Table 4

Drop Ball Data

| Variable | Drop Ball Pitchers | | Rise Ball Pitchers | |
|---|---|---|---|---|
| | Mean | Standard Deviation | Mean | Standard Deviation |
| Velocity | 86.34 ft/sec | 1.11 ft/sec | 77.09 ft/sec | 3.83 ft/sec |
| Hip Rotation | 48.07 degrees | 23.80 degrees | 60.24 degrees | 9.29 degrees |
| Shoulder Rotation | 59.89 degrees | 6.97 degrees | 67.49 degrees | 15.60 degrees |
| Trail Foot Angle | 22.21 degrees | 15.20 degrees | 11.72 degrees | 3.66 degrees |
| Lead Foot Angle | 14.58 degrees | 5.78 degrees | 28.06 degrees | 5.35 degrees |
| Trunk Inclination/ Weight Shift | 32.17 degrees | 3.83 degrees | 26.52 degrees | 13.30 degrees |

Table 4 - Continued

| Variable | Drop Ball Pitchers | | Rise Ball Pitchers | |
|---|---|---|---|---|
| | Mean | Standard Deviation | Mean | Standard Deviation |
| Trunk Inclination/ Release | 8.02 degrees | 2.56 degrees | 8.95 degrees | 5.76 degrees |
| Hip Closure | 11.30 degrees | 16.00 degrees | 30.92 degrees | 1.77 degrees |
| Shoulder Closure | 6.36 degrees | 8.99 degrees | 27.96 degrees | 2.14 degrees |
| Stride Length | 58.06% | 7.92% | 46.75% | 9.82% |
| Shoulder Torque | -2837.85 lb-ft | 4013.00 lb-ft | 5107.65 lb-ft | 2910.00 lb-ft |
| Wrist Torque | 921.80 lb-ft | 1490.00 lb-ft | -799.90 lb-ft | 1126.00 lb-ft |

For the rise ball pitchers, the mean value was 60.24 degrees while the standard deviation was computed to be 9.29 degrees. In other words, it appears that a lesser amount of hip rotation contributes to a better drop ball.

## The Maximum Degree of Shoulder Rotation

The mean value for the drop ball pitchers was 59.89 degrees while the standard deviation was 6.97 degrees. For the rise ball pitchers, the mean value was 67.49 degrees while the standard deviation was calculated to be 15.60 degrees. In other words, it appears that a lesser amount of shoulder rotation contributes to a better drop ball.

## The Angle of the Trail Foot During the Weight Shift

The mean value for the drop ball pitchers was 22.21 degrees while the standard deviation was 15.20 degrees. For the rise ball pitchers, the mean value was 11.72 degrees while the standard deviation was computed to be 3.66 degrees. These results suggest that a better drop ball can be thrown if the trail foot is turned to a greater extent during the weight shift.

## The Angle of the Lead Foot at Foot Plant

The mean value for the drop ball pitchers was 14.58 degrees while the standard deviation was 5.78 degrees. For the rise ball pitchers, the mean value was 28.06 degrees while the standard deviation was calculated to be 5.35 degrees. These results suggest that a better drop ball can be thrown if the lead foot is only slightly turned at foot plant.

## The Degree of Trunk Inclination During the Weight Shift

The mean value for the drop ball pitchers was 32.17 degrees while the standard deviation was 3.83 degrees. For the rise ball pitchers, the mean value was 26.52 degrees while the standard deviation was computed to be 13.30 degrees. These results suggest that a greater amount of trunk inclination during the weight shift contributes to a better drop ball.

## The Degree of Trunk Inclination at Release

The mean value for the drop ball pitchers was 8.02 degrees while the standard deviation was 2.56 degrees. For the rise ball pitchers, the mean value was 8.95 degrees while the standard deviation was calculated to be 5.76 degrees. These results suggest that it is not the amount of trunk inclination at release which distinguishes a good drop ball pitcher from a poorer one.

The Degree of Hip Closure at Release

The mean value for the drop ball pitchers was 11.30 degrees while the standard deviation was 16.00 degrees. For the rise ball pitchers, the mean value was 30.92 degrees while the standard deviation was computed to be 1.77 degrees. In other words, it appears that a greater amount of hip closure contributes to a better drop ball.

The Degree of Shoulder Closure at Release

The mean value for the drop ball pitchers was 6.36 degrees while the standard deviation was 8.99 degrees. For the rise ball pitchers, the mean value was 27.96 degrees while the standard deviation was calculated to be 2.14 degrees. In other words, it appears that a greater amount of shoulder closure contributes to a better drop ball.

The Stride Length

The mean value for the drop ball pitchers was 58.06% while the standard deviation was 7.92%. For the rise ball pitchers, the mean value was 46.75% while the standard deviation was computed to be 9.82%. These results indicate that the good drop ball pitchers took a longer stride than the poorer drop ball pitchers did.

## The Torque About the Shoulder During the Arm's Downswing

The mean value for the drop ball pitchers was -2837.85 lb-ft while the standard deviation was 4013.00 lb-ft. For the rise ball pitchers, the mean value was 5107.65 lb-ft while the standard deviation was calculated to be 2910.00 lb-ft. In other words, the good drop ball pitchers' arms tended to be decelerating as they began their downward motion.

## The Torque About the Wrist at Release

The mean value for the drop ball pitchers was 921.80 lb-ft while the standard deviation was 1490.00 lb-ft. For the rise ball pitchers, the mean value was -799.90 lb-ft while the standard deviation was computed to be 1126.00 lb-ft. In other words, the good drop ball pitchers' hands tended to be accelerating about the wrist as the pitch was released.

## Discussion of the Drop Ball Results

Based upon the data presented in *Table 4*, the investigator made the following conclusions:

1. The drop ball must be thrown with a great deal of velocity.

2. A lesser amount of hip and shoulder rotation contributes to a better drop ball.

3. A greater amount of hip and shoulder closure leads to a more successful drop ball.

When comparing the information contained in Table 4 with that found in Table 3, the investigator discovered the following to be true:

1. Subjects 6, 7, and 8 had their trail foot turned to a lesser extent during the weight shift when pitching a drop ball than they did when throwing a rise. The good drop ball pitchers, on the other hand, turned this foot to a greater degree when throwing a drop ball than the rise ball pitchers did. This seems to suggest that it is not the angle of the trail foot during the weight shift which distinguishes between a good drop ball pitcher and a poorer one.

2. Subjects 6, 7, and 8 had their lead foot turned to the same extent at foot plant no matter which pitch they threw. The good drop ball pitchers, on the other hand, had this foot turned to a lesser degree when throwing a drop ball than the rise ball pitchers did. This appears to indicate that it is not the angle of the

lead foot at foot plant which distinguishes between a good drop ball pitcher and a poorer one.

3. Subjects 6, 7, and 8 leaned over to the same extent during the weight shift no matter which pitch they threw. The good drop ball pitchers, on the other hand, were bent over to a greater extent during the weight shift when throwing a drop ball than the rise ball pitchers were. This seems to suggest that it is not the degree of trunk inclination during the weight shift which distinguishes a good drop ball pitcher from a poorer one.

4. Subjects 6, 7, and 8 were bent forward slightly as they released the drop ball and were leaning backwards as they let go of the rise. The good drop ball pitchers, on the other hand, were bent over to the same extent when delivering the drop ball as the rise ball pitchers were. This appears to indicate that it is not the degree of trunk inclination at release which distinguishes a good drop ball pitcher from a poorer one.

5. Subjects 6, 7, and 8 took a shorter stride when throwing a drop ball than they did when pitching a rise. The good drop ball pitchers, on the other hand, took a longer stride when throwing a drop ball than the rise ball pitchers did. This seems to suggest that stride length is not a distinguishing factor between good drop ball pitchers and poorer ones.

6. Subjects 6, 7, and 8 had a positive mean value for the amount of torque about the shoulder during the arm's downswing while the good drop ball pitchers had a negative mean value. This appears to indicate that shoulder torque is not a distinguishing factor between good drop ball pitchers and poorer ones.

7. Subjects 6, 7, and 8 had a negative mean value for the amount of torque about the wrist at release while the good drop ball pitchers had a positive mean value. This seems to suggest that wrist torque is not a distinguishing factor between good drop ball pitchers and poorer ones.

## A Descriptive Analysis of the Rise Ball

Table 5 displays the mean and standard deviation calculated for the drop ball and rise ball pitchers on each of the 12 variables associated with a rise ball using the windmill style softball delivery. Again, Subjects 1, 2, and 3 were considered to be the rise ball pitchers and Subjects 4 and 5 were the drop ball pitchers. The interpretation of each mean and standard deviation is discussed in this section.

Table 5

Rise Ball Data

| Variable | Drop Ball Pitchers | | Rise Ball Pitchers | |
|---|---|---|---|---|
| | Mean | Standard Deviation | Mean | Standard Deviation |
| Velocity | 80.20 ft/sec | 2.38 ft/sec | 81.60 ft/sec | 5.79 ft/sec |
| Hip Rotation | 50.20 degrees | 19.90 degrees | 65.24 degrees | 4.39 degrees |
| Shoulder Rotation | 64.31 degrees | 5.83 degrees | 71.96 degrees | 14.60 degrees |
| Trail Foot Angle | 24.78 degrees | 14.70 degrees | 12.09 degrees | 11.60 degrees |
| Lead Foot Angle | 20.46 degrees | 5.83 degrees | 38.35 degrees | 32.20 degrees |
| Trunk Inclination/ Weight Shift | 32.98 degrees | 4.31 degrees | 32.89 degrees | 10.80 degrees |

Table 5 - Continued

| Variable | Drop Ball Pitchers | | Rise Ball Pitchers | |
|---|---|---|---|---|
| | Mean | Standard Deviation | Mean | Standard Deviation |
| Trunk Inclination/ Release | 3.33 degrees | 4.15 degrees | 5.63 degrees | 11.60 degrees |
| Hip Closure | 14.32 degrees | 20.30 degrees | 30.89 degrees | 2.16 degrees |
| Shoulder Closure | 10.55 degrees | 14.90 degrees | 28.62 degrees | 5.19 degrees |
| Stride Length | 61.23% | 4.16% | 59.99% | 6.18% |
| Shoulder Torque | -7322.53 lb-ft | 2881.00 lb-ft | -1338.48 lb-ft | 6763.00 lb-ft |
| Wrist Torque | 142.31 lb-ft | 719.00 lb-ft | 147.29 lb-ft | 3497.00 lb-ft |

The Velocity of the Pitch at Release

The mean value for the drop ball pitchers was 80.20 ft/sec while the standard deviation was 2.38 ft/sec. For the rise ball pitchers, the mean value was 81.60 ft/sec while the standard deviation was calculated to be 5.79 ft/sec. These results suggest that it is not the magnitude of the pitch's velocity which distinguishes a good rise ball pitcher from a poorer one.

The Maximum Degree of Hip Rotation

The mean value for the drop ball pitchers was 50.20 degrees while the standard deviation was 19.90 degrees. For the rise ball pitchers, the mean value was 65.24 degrees while the standard deviation was computed to be 4.39 degrees. In other words, it appears that a greater amount of hip rotation contributes to a better rise ball.

The Maximum Degree of Shoulder Rotation

The mean value for the drop ball pitchers was 64.31 degrees while the standard deviation was 5.83 degrees. For the rise ball pitchers, the mean value was 71.96 degrees while the standard deviation was calculated to be 14.60 degrees. In other words, it appears that a greater amount of shoulder rotation contributes to a better rise ball.

## The Angle of the Trail Foot During the Weight Shift

The mean value for the drop ball pitchers was 24.78 degrees while the standard deviation was 14.70 degrees. For the rise ball pitchers, the mean value was 12.09 degrees while the standard deviation was computed to be 11.60 degrees. These results suggest that a better rise ball can be thrown if the trail foot is only slightly turned during the weight shift.

## The Angle of the Lead Foot at Foot Plant

The mean value for the drop ball pitchers was 20.46 degrees while the standard deviation was 5.83 degrees. For the rise ball pitchers, the mean value was 38.35 degrees while the standard deviation was calculated to be 32.20 degrees. These results suggest that a better rise ball can be thrown if the lead foot is turned to a greater extent at foot plant.

## The Degree of Trunk Inclination During the Weight Shift

The mean value for the drop ball pitchers was 32.98 degrees while the standard deviation was 4.31 degrees. For the rise ball pitchers, the mean value was 32.89 degrees while the standard deviation was computed to be 10.80 degrees. These results suggest that it is not the amount of trunk inclination during the weight shift which distinguishes a good rise ball pitcher from a poorer one.

### The Degree of Trunk Inclination at Release

The mean value for the drop ball pitchers was 3.33 degrees while the standard deviation was 4.15 degrees. For the rise ball pitchers, the mean value was 5.63 degrees while the standard deviation was calculated to be 11.60 degrees. These results suggest that it is not the amount of trunk inclination at release which distinguishes a good rise ball pitcher from a poorer one.

### The Degree of Hip Closure at Release

The mean value for the drop ball pitchers was 14.32 degrees while the standard deviation was 20.30 degrees. For the rise ball pitchers, the mean value was 30.89 degrees while the standard deviation was computed to be 2.16 degrees. In other words, it appears that a lesser amount of hip closure contributes to a better rise ball.

### The Degree of Shoulder Closure at Release

The mean value for the drop ball pitchers was 10.55 degrees while the standard deviation was 14.90 degrees. For the rise ball pitchers, the mean value was 28.62 degrees while the standard deviation was calculated to be

5.19 degrees. In other words, it appears that a lesser amount of shoulder closure contributes to a better rise ball.

## The Stride Length

The mean value for the drop ball pitchers was 61.23% while the standard deviation was 4.16%. For the rise ball pitchers, the mean value was 59.99% while the standard deviation was computed to be 6.18%. These results indicate that it is not the stride length which distinguishes a good rise ball pitcher from a poorer one.

## The Torque About the Shoulder During the Arm's Downswing

The mean value for the drop ball pitchers was -7322.53 lb-ft while the standard deviation was 2881.00 lb-ft. For the rise ball pitchers, the mean value was -1338.48 lb-ft while the standard deviation was calculated to be 6763.00 lb-ft. In other words, the good rise ball pitchers' arms were decelerating to a lesser extent than were the poorer rise ball pitchers' arms.

## The Torque About the Wrist at Release

The mean value for the drop ball pitchers was 142.31 lb-ft while the standard deviation was 719.00 lb-ft. For the rise ball pitchers, the mean value was

147.29 lb-ft while the standard deviation was computed to be 3497.00 lb-ft. In other words, it appears that it is not the amount of torque about the wrist which distinguishes a good rise ball pitcher from a poorer one.

## Discussion of the Rise Ball Results

Based upon the data presented in Table 5, the investigator made the following conclusions:

1. A greater amount of hip and shoulder rotation contributes to a better rise ball.

2. A lesser amount of hip and shoulder closure leads to a more successful rise ball.

When comparing the information contained in Table 5 with that found in Table 3, the investigator discovered the following to be true:

1. Subjects 6, 7, and 8 threw the rise ball slower than the drop. The good rise ball pitchers, on the other hand, threw the rise ball with approximately the same amount of velocity as the drop ball pitchers did. This appears to indicate that the velocity of the pitch is not a distinguishing factor between good rise ball pitchers and poorer ones.

2. Subjects 6, 7, and 8 had their trail foot turned to a greater extent during the weight shift when pitching a rise ball than they did when throwing a drop. The good

rise ball pitchers, on the other hand, turned this foot to a lesser degree when throwing a rise ball than the drop ball pitchers did. This seems to suggest that it is not the angle of the trail foot during the weight shift which distinguishes between a good rise ball pitcher and a poorer one.

3. Subjects 6, 7, and 8 had their lead foot turned to the same extent at foot plant no matter which pitch they threw. The good rise ball pitchers, on the other hand, had this foot turned to a greater degree when throwing a rise ball than the drop ball pitchers did. This appears to indicate that it is not the angle of the lead foot at foot plant which distinguishes between a good rise ball pitcher and a poorer one.

4. Subjects 6, 7, and 8 leaned over to the same extent during the weight shift no matter which pitch they threw. Likewise, the good rise ball pitchers were bent over to the same extent at the beginning of the rise ball motion as the drop ball pitchers were. This seems to suggest that it is not the degree of trunk inclination during the weight shift which distinguishes a good rise ball pitcher from a poorer one.

5. Subjects 6, 7, and 8 were bent forward slightly as they released the drop ball and were leaning backwards as they let go of the rise. The good rise ball pitchers,

on the other hand, were bent over to the same extent when delivering the rise ball as the drop ball pitchers were. This appears to indicate that it is not the degree of trunk inclination at release which distinguishes a good rise ball pitcher from a poorer one.

6. Subjects 6, 7, and 8 took a longer stride when throwing a rise ball than they did when pitching a drop. The good rise ball pitchers, on the other hand, took approximately the same length of stride when throwing a rise ball as the drop ball pitchers did. This seems to suggest that stride length is not a distinguishing factor between good rise ball pitchers and poorer ones.

7. Subjects 6, 7, and 8 had a large negative mean value for the amount of torque about the shoulder during the arm's downswing while the good rise ball pitchers had a smaller negative mean value. This appears to indicate that shoulder torque is not a distinguishing factor between good rise ball pitchers and poorer ones.

8. Subjects 6, 7, and 8 had a positive mean value for the amount of torque about the wrist when delivering the rise ball while they had a negative mean value when releasing the drop. The good rise ball pitchers, on the other hand, had approximately the same amount of torque about the wrist when they threw the rise ball as the drop ball pitchers had. This seems to suggest that wrist

torque is not a distinguishing factor between good rise ball pitchers and poorer ones.

## Summary

Based upon the values presented in Table 1, the investigator concluded that the group of subjects was fairly homogeneous with respect to two variables, the velocity of the pitch at release and the stride length, and extremely heterogeneous with respect to the other 10 variables. It was also discovered that: (a) the subjects did not tend to completely turn their hips and shoulders during the execution of a pitch; (b) the subjects tended to turn their trail foot outward during the weight shift and their lead foot in the direction of the throwing arm side at foot plant; (c) the subjects tended to lean over as they began their motion and be upright as they released the pitch; (d) the subjects did not tend to have their hips and shoulders completely facing home plate as the softball was released; and (e) the subjects tended to use a stride which was slightly over one-half of their standing height.

The values in Table 2 led the investigator to conclude that there were no high relationships between the velocity of the pitch at release and any of the other variables. This seems to indicate that a combination of proper pitching mechanics is necessary in order to throw a good fast ball. In other words, there is no one variable which seems to be the primary reason that a pitcher can throw the ball hard.

Table 3, Table 4, and Table 5 presented information regarding the drop ball and rise ball. From these tables, it was concluded that: (a) the velocity of a drop ball was greater than that of a rise ball; (b) the degree of maximum hip and shoulder rotation was greater for the execution of a rise ball; (c) the angle of the trail foot during the weight shift and the lead foot at foot plant was not a distinguishing factor between good drop ball pitchers and good rise ball pitchers; (d) the degree of trunk inclination during the weight shift and at release was not a distinguishing factor between good drop ball pitchers and good rise ball pitchers; (e) the degree of hip and shoulder closure at release was greater for the execution of a drop ball; (f) the stride length was not a distinguishing factor between good drop ball pitchers and good rise ball pitchers; and (g) the amount of torque about the shoulder during the arm's downswing and about the wrist at release was not a distinguishing factor between good drop ball pitchers and good rise ball pitchers.

# CHAPTER V

## SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

### Summary

The problem of the study was to identify the specific kinematic and kinetic variables associated with a successful fast ball, drop ball, and rise ball using the windmill style softball delivery. The subjects chosen for the investigation were 18 female pitchers who participated in the Women's National Fast-Pitch Softball Tournament held in Buffalo, New York from August 17, 1984 to August 24, 1984. Although this group of subjects included both windmill style and slingshot style pitchers, only the data produced by the 16 windmill pitchers were considered for analysis.

During the filming procedures, the subjects were instructed to perform three trials of the three different types of pitches. In other words, the investigator filmed three fast balls, three drop balls, and three rise balls for each subject. Upon completion of each set of pitches, the subjects were asked to determine which of the three trials represented their best effort. Thus, only one trial of each type of pitch was considered for analysis.

The filming was done with the aid of two Photo-Sonics Biomechanics 500 cameras, each equipped with a 12 - 120 mm lens. Once the film was developed, the investigator used a Vanguard Motion Analyzer, a Numonics electronic digitizer, and an Apple II Plus computer to analyze the 12 variables associated with a successful windmill style softball pitch. Specifically, these variables included: (a) the velocity of the pitch at release; (b) the maximum degree of hip rotation; (c) the maximum degree of shoulder rotation; (d) the angle of the trail foot during the weight shift; (e) the angle of the lead foot at foot plant; (f) the degree of trunk inclination during the weight shift; (g) the degree of trunk inclination at release; (h) the degree of hip closure at release; (i) the degree of shoulder closure at release; (j) the stride length; (k) the torque about the shoulder during the arm's downswing; and (l) the torque about the wrist at release.

## Findings

The findings of the study were as follows:

1. The group of subjects was fairly homogeneous with respect to two fast ball variables, the velocity of the pitch at release and the stride length.

2. The group of subjects was extremely heterogeneous with respect to the other 10 variables associated with a fast ball.

3. There were no high relationships between the velocity of the fast ball at release and any of the other variables associated with a fast ball.

4. The velocity of a drop ball was greater than that of a rise ball.

5. The degree of maximum hip and shoulder rotation was greater for the execution of a rise ball.

6. The degree of hip and shoulder closure at release was greater for the execution of a drop ball.

7. There was relatively little distinction between the execution of a drop ball and that of a rise ball with respect to the angle of the trail foot during the weight shift, the angle of the lead foot at foot plant, the degree of trunk inclination during the weight shift, the degree of trunk inclination at release, the stride length, the amount of torque about the shoulder during the arm's downswing, and the amount of torque about the wrist at release.

## Conclusions

Based upon the results of this investigation, the following conclusions were made:

1. In order to throw a successful fast ball, pitchers should use a stride which is slightly greater than one-half of their standing height.

2. A combination of proper pitching mechanics is necessary in order to throw a good fast ball. There is no one variable which solely contributes to the success of this pitch.

3. There is a great deal of variability between the fast ball pitching mechanics of elite windmill style softball pitchers.

4. A large amount of hip and shoulder rotation is necessary when throwing a rise ball while a smaller amount is essential when pitching a drop. In other words, the more a pitcher turns the hips and shoulders during the execution of a rise ball, the more successful the pitch will be. Conversely, a better drop ball can be thrown if the pitcher turns the hips and shoulders to a lesser extent.

5. A large amount of hip and shoulder closure is necessary when throwing a drop ball while a smaller amount is essential when pitching a rise. In other words, the more nearly a pitcher's hips and shoulders are facing home plate as the drop ball is released, the more successful the pitch will be. Conversely, a better rise ball can be thrown if the pitcher's hips and shoulders are not facing home plate at release.

## Recommendations

The results of this study prompted the investigator to make the following recommendations:

1. The study should be repeated using male subjects.

2. The study should be repeated using a three-dimensional analysis of the specific kinematic and kinetic variables.

3. An investigation should be undertaken in which the pitching mechanics of a windmill style pitcher are compared with those used by a slingshot style pitcher.

APPENDICES

APPENDIX A

SAMPLE QUESTIONNAIRE

QUESTIONNAIRE

NAME ________________________________________ AGE __________

PERMANENT ADDRESS ________________________________________

________________________________________

NAME OF SUMMER SOFTBALL TEAM ______________________________

CURRENT SEASON PITCHING RECORD ______________________
(PRIOR TO THIS TOURNAMENT)

CURRENT SEASON EARNED RUN AVERAGE ____________________
(PRIOR TO THIS TOURNAMENT)

ARE YOU A RIGHT-HANDED OR LEFT-HANDED PITCHER? ___________

ARE YOU A WINDMILL OR A SLINGSHOT PITCHER? _______________

AT WHAT AGE DID YOU PITCH IN YOUR FIRST GAME? ____________

WHAT MADE YOU DECIDE TO BECOME A PITCHER?

HOW DID YOU DECIDE UPON A PITCHING STYLE (WINDMILL VS. SLINGSHOT)?

WHICH PITCH TOOK YOU THE LONGEST TIME TO DEVELOP, THE RISE BALL OR THE DROP BALL? WHY?

PLEASE RANK ORDER THE VARIOUS PITCHES YOU THROW IN ACTUAL COMPETITION LISTING YOUR BEST PITCH FIRST AND YOUR WORST PITCH LAST.

WHAT PERCENTAGE OF TIME DO YOU USE EACH OF THE ABOVE PITCHES DURING AN AVERAGE GAME?

PLEASE LIST THE TEAMS YOU HAVE PLAYED WITH DURING YOUR CAREER AND INDICATE THE NUMBER OF YEARS YOU HAVE PLAYED WITH EACH (SEE BELOW).

COLLEGE:

1. ______________________________

2. ______________________________

AMATEUR (ASA):

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

5. ______________________________

PROFESSIONAL:

1. ______________________________

2. ______________________________

APPENDIX B

SAMPLE DATA SHEET

| NO. | NAME | STYLE | DOM. HAND | HEIGHT | WEIGHT | WEIGHT OF SB | WIDTH OF PG | WIDTH OF SG | L. TOE TO HEEL | L. ANKLE TO HEEL | R. TOE TO HEEL | R. ANKLE TO HEEL | BEST FB | BEST DROP | BEST RISE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
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