A COMPARISON OF SELECTED MECHANICAL FACTORS IN MALE BASEBALL AND FEMALE FAST PITCH SOFTBALL BATTING

by

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This thesis is dedicated to my grandparents, Esther and Elwyn Gehman, with my deepest appreciation for their constant belief in me and the importance of education.

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CHAPTER 1

INTRODUCTION

Batting has been described as the most difficult skill in sport (Williams and Underwood, 1968), and as such has been the focus of analysis by spectators, players, coaches, and ultimately, researchers. It is an inherently frustating task in which the best batters still fail approxiamately seventy percent of the time. It is also a task which both males and females have attempted to master, in the games of baseball and fast pitch softball, respectively. All batters face the prospect of meeting a ball travelling toward them at 80 to 100 miles per hour with their forward swinging bat, a narrow striking implement when compared with most other sport striking implements (eg. tennis racket). The batter has less than one half of a second to decide where the pitched ball is going, whether he/she wants to swing at it, and to complete the swing. There is not much time for corrections to be made during the swing; therefore, batters must develop consistent and sound swing patterns to experience success in baseball and softball batting.

Researchers investigating batting have predominantly studied male baseball batters, leaving softball batters and coaches on the sidelines of the research. A dedicated female fast pitch softball batter has very little information available to assist her, and must examine the research done with male baseball batters in hopes that the research will apply to her as well. There are several problems inherent in assuming that male baseball batting and female softball batting are comparable. Although the game objectives are the same and the tasks are similar, they are far from identical. The pitcher in baseball is 60 feet 6 inches away from the batter, while in softball that distance is only 46 feet; yet the pitchers in both sports deliver the ball at similar speeds (Hay, 1978). Thus, the softball pitcher gets the ball to the plate in less time than the baseball pitcher, giving the softball batter less time to watch the pitched ball and complete her swing than the baseball batter. Even more important to this investigation are the physical and mechanical differences between males and females which may affect the swing. For example, hip width, location of total body center of gravity, proportionate mass of body segments, and upper body strength are potentially significant differences between the two groups relative to batting.

For these reasons, research of the mechanics of males batting baseballs cannot validly be applied to the female softball batter without modification. The extent to which these factors apply to female batters needs to be determined. In addition, direct comparisons between males and females within the same investigation is needed to control for procedural variability. The degree of difference between the performances and the mechanics of male and female batters has not been explored.

Statement of the Problem

The purpose of this investigation was to compare selected mechanical factors in male and female batters hitting a wiffle ball off of a batting tee using their customary bat and swing pattern. Specifically, the ground reaction forces in the lead foot in the lateral and vertical planes and torque about the vertical axis were measured and synchronized with the subjects' batting movements. Specific variables selected for comparison were hip and trunk rotation, linear and angular velocities and accelerations of the upper body segments and bat, and the timing sequence of maximum velocities acheived by each segment and the bat center of percussion relative to bat-ball impact.

Significance of the Study

This study is significant in that it describes and defines selected mechanical and kinetic factors in female softball batting, a sport skill few researchers have investigated. In addition, this study is unique in that it utilizes both male and female batters performing the same task, allowing direct comparison between the two groups. Finally, the use of lead foot force data and filmed kinematic data enables this investigation to relate the batters' footwork with the resultant swing. All of these factors would be especially beneficial to the female batter or fast pitch softball coach who is interested in understanding and improving batting, as well as interpreting the extent to which the research utilizing male batters can be applied to female batters.

Hypotheses

The following hypotheses were proposed and tested in this investigation.

1. Male subjects will have significantly higher maximum linear bat velocities than female subjects.

2. Male subjects will have higher angular hip, trunk, arm and bat velocities than female subjects.

3.Male subjects will have higher linear arm, forearm, hand and bat velocities than female subjects.

4. Male subjects will have higher lead foot ground reaction forces relative to their body weight in the lateral and vertical planes than female subjects.

5. Males will have higher torque values about the vertical axis of the lead foot relative to their body weight than females.

6. Males will acheive greater elbow extension before impact than females.

7. Males will reach maximum linear and angular velocities of the upper extremities and bat earlier than females.

Delimitations

The following factors were considered to be the delimitations of this investigation. The subjects were starting players of Division I midwestern intercollegiate varsity baseball and softball teams. The subjects volunteered for the study and were all classified as consistent hitters by their respective coaches. Only movements in the horizontal plane were observed in the film analysis.

Definitions of Terms

Softball

This investigation refers to the sport of women's fast pitch softball simply as softball. Slow pitch softball hitting was not investigated.

Center of percussion

Also known as the sweet spot of the bat, this is the point on the bat relative to the batter's grip which, when impacted, results in no reaction forces back at the batter's hands.

Vertical force

Ground reaction forces of the batter's lead foot in the vertical plane (up and down) expressed as a percentage of the subject's body weight.

Lateral force

Ground reaction forces of the batter's lead foot in the lateral plane (toward the pitcher) expressed as a percentage of the subject's body weight.

Twist torque

The rotational effect of force about the vertical axis of the batter's lead foot.

CHAPTER 2

REVIEW OF THE LITERATURE

The literature reviewed for this investigation is divided into three parts: (1) the mechanics of baseball batting, (2) strength and structural considerations, and (3) female softball batting mechanics. The majority of batting research has utilized male baseball batters; however, a thorough understanding of baseball batting is useful for comparison with the more limited data available on female batters. Thus, the first section of literature reviewed concerns the mechanics of baseball batting.

The Mechanics of Baseball Batting

Baseball batting is essentially a sidearm striking movement pattern in which the batter attempts to impart maximum velocity to the impacted ball in the desired direction. This is accomplished by generating maximum linear bat velocity at impact. The batter uses a sequence of segmental rotations not unlike the motion of a whip. This is called the kinetic link principle. Krieghbaum and Barthels (1985) define the kinetic link as: "The generation of high end-point velocity accomplished through the use of accelerating and deccelerating adjoining links, by the use of internal and external muscle torques, applied to the segments in a sequential manner from proximal to distal, from most massive to least massive, and from most fixed to most free."

As a segment reaches its maximum velocity, it applies force to the next segment. Because the segments progress from heavy to light, velocity increases as momentum is conserved. The result is high end-point velocity, or in this case, high bat velocity. The distal segments often lag behind the initial movement by the larger, proximal segments. This tendency to lag back actually lengthens the resting length of the muscles in the distal segments, allowing greater tension to be exerted when their turn in the kinetic link sequence occurs. Baseball batting is a specific sidearm striking skill which utilizes the kinetic link principle in its mechanics.

The mechanics of hitting a baseball have been described by Hay (1978), who divided the hitting movement into four phases; the stance, stride, swing and follow through. These phases are useful subdivisions for analysis, and the research reviewed in this section will be grouped according to movement phase. An overview of the four phases is presented first.

Hay (1978) described the stance as the position of the batter in the box, with the batter's frontal plane parallel to the flight of the ball pitched from the mound to home plate. The feet of the batter should be slightly wider than shoulder width apart, with most of the weight on the back foot. The stride occurs as the front foot moves in the general direction of the pitcher, and covers 12 inches or less. Hay described a cocking of the hip inward during the stride, which ends when the front foot is planted. The swing is initiated .04 seconds after foot plant, and consists of a sequential rotation of the hips, shoulders, and then arm swing when the shoulders rotate to a point even with the hips. The sequence continues with the arm swing, left wrist adduction prior to contact, and ultimately, the bat attaining maximum linear velocity toward the ball at impact. After ball contact, the follow through is a natural winding down of the swing. Research investigating specific phases of baseball batting is presented next, beginning with the stance.

Stance

Hay (1978) examined the advantages and disadvantages associated with different stances. The closed stance, with the lead foot positioned toward right field (right handed batter), results in more hip cocking before the swing. This allows the batter to exert muscular forces rotating the hips and shoulders over a longer distance, thereby doing more work and applying more force to the ball. However, the rotation sequence with a closed stance takes more time to complete than for a parallel or open stance. The open stance, in which the lead foot is positioned toward left field (right handed batter), allows for a quicker swing because the hips and shoulders are partially rotated before the foot is planted and the swing begins. Less rotation may be an advantage for the slower batter, but allows less work to be done and therefore less force applied by the bat. The most often used stance, parallel, is a compromise between the previous two stances in which both feet are positioned in line with the pitcher. Cece (1975) investigated stance and bat velocity with college baseball batters hitting off of a batting tee at waist height. He found no differences between the open, closed and parallel stances and bat velocity. Cece also investigated stride length in this study, which is presented in the next section.

Stride

Regardless of which stance is used, Hay (1978) pointed out that a short, even stride is desirable. This allows the batter's center of gravity to remain in a level plane close enough to the back foot to produce forceful hip rotation during the swing. This is accomplished by bracing both feet against the ground firmly. Breen (1967) studied films of six major league career .300 hitters. He concluded that all of these excellent hitters had several batting fundamentals in common. Their body center of gravity followed a level plane throughout the swing, the stride length was consistent for each subject, and the batter's weight was on the front foot after contact. Ted Williams also concurred with Hay and Breen in his informal sudy of himself and his peers throughout his illustrious career (Williams and Underwood, 1968). He emphasized a consistent stride and smooth movement of the body center of gravity for effective hitting.

Cece (1975) studied the relationship between stride length and bat velocity, and reported an increase in bat velocity as stride length increased from 6 to 14 inches. This finding is unusual, and has not been supported by others. Shapiro (1974), and Breen (1967) have noted no relationship between stride length and bat velocity; in fact, effective batters against live pitching have tended to use shorter strides. Cece used batting tees in his study, which may have influenced his results. Overall, the research indicates that consistent stride length and direction is associated with batting skill (Shapiro, 1974).

Swing

Several researchers have noted that full extension of the lead arm during the swing increases the radius of the swing and the linear velocity of the bat (Hay, 1978, Breen, 1967, Williams and Underwood, 1968). Hay further described the desired movement of the swing:

> "So that the bat can be appropriately aligned when it is brought forward to meet the ball and so that forces exerted on the ball impart to it a velocity in the desired direction, the rotation of the hips, shoulders and arms should each take place in an approxiamately horizontal plane."

The effective batter swings in a horizontal plane, with arms extended, wrists firm and the legs and hips braced against each other to apply maximum force to the ball (Hay, 1978). Other researchers have measured various aspects of the effective swing.

Shapiro (1979) measured maximum linear velocity of male collegiate batters at the center of mass of the bat using three-dimensional filming techniques. The mean value for his subjects was 30.3 meters per second at impact. Shapiro also described the sequential rotation of body parts beginning with the hips and ending with the wrists and bat.

The link principle of body segment rotations was described in an earlier study by Race (1961). He filmed 19 professional batters and found that the velocity of body parts increased from the feet to the hips to the wrists. He concluded that the "rotary motion initiated by rather dramatic hip rotation and culminated by quick and powerful wrist action" was the most important factor in effective hitting. Another interesting measurement made by Race was the swing time of the subjects. He defined swing time as the time from initial bat movement forward to ball contact. Race found swing times ranging from .16 to .28 seconds for his subjects, with a mean swing time of .19 seconds. Hay (1978) and Ted Williams (Williams and Underwood, 1968) noted that a fast swing time means more time to watch the pitch and decide when and where to swing, if at all.

Magarian (1975) took the research on swing time one step further. He correlated bat performance time with batting average and slugging percentage of fifty one intercollegiate baseball players from six college teams. He defined bat performance time as the time from a light stimulus to ball contact during the subsequent swing (essentially reaction time plus swing time). The mean bat performance time for all subjects was .48 seconds, with a standard deviation of .03 seconds. Both batting average and slugging percentage were positively correlated with bat performance time. Evidently, bat speed is essential to good hitting for two reasons; to impart maximum velocity to the ball, and to increase the amount of time the batter can watch the pitch before swinging.

Other Batting Studies

Researchers have investigated male baseball batting further by comparing types of hitters. Pike (1974) studied the mechanics of two batters, one a power hitter and the other a punch hitter. The power hitter had six years of professional baseball experience, while the punch hitter was a four-year varsity college player. The power hitter used a closed stance and had greater hip rotation than the punch hitter, who used an open stance. The power hitter also had a longer stride, greater shoulder rotation by 25 degrees, and higher linear velocities of the elbow, wrist and bat than the punch hitter. The punch hitter, who primarily tried to contact the ball and hit to the opposite field, accelerated the bat linearly over a longer period of time and had less elbow extension at contact than the power hitter. These results indicate the power hitter's desire for maximum ball velocity after impact as opposed to the punch hitter's attempts to place the ball. The closed stance, hip and shoulder rotation, and elbow extension of the power hitter increased the linear velocity of his arms and the bat. Pike also reported that both batters reached maximum linear bat velocity before contact, despite their experience and skill level.

A more recent study compared 20 subjects hitting to the same field and the opposite field. McIntyre and Pfautsch (1982) had their male subjects hit in both conditions and compared the mechanics involved in the two types of hitting. The subjects hit balls pitched from a pitching machine and were filmed from above for all trials. The authors stated that "the movements of interest occurred primarily in the horizontal plane perpendicular to the optical axis of the camera." This assumption is supported by Hay (1978) as previously cited. Measurements were made of the tip of the bat, handle of the bat, third metacarpal of the left hand, left wrist, left shoulder, left elbow and the ball. All batters were right handed. Higher linear and angular velocities at the tip of the bat were recorded for batters hitting to the same field. The authors also reported a summated contribution of the upper limb segments to bat velocity. Batters in this study reached maximum bat linear velocity .013 to .016 seconds before contact. These results support Pike's research previously described.

A final group of studies have tried to determine which parts of the body were most responsible for generating bat velocity. Puck (1964) used three synchronized cameras to film four right handed collegiate baseball batters. He described mechanics similar to Hay (1978), and measured average trunk rotation of 119 degrees for the four subjects. He concluded that the hips and shoulders in rotation contributed most to force. Ryan (1973) attributed 50% of the linear velocity of the bat to wrist adduction prior to contact, but also considered the initiation of hip rotation important to the successful swing. French (1970) found significant relationships between trunk rotation, leg strength and bat velocity. Thus, most researchers agree that the sequential rotation and increasing velocities of the batter's hips, shoulders, arms and wrists are essential to generate high bat velocities. The stride and initiation of hip rotation begin the sequence, and therefore are crucial to the swing. Arm extension and wrist adduction prior to contact dramatically increase linear bat velocity. These fundamental body movements used in the mechanics of effective baseball batting are dependant upon the subject's muscular strength and structure. The muscular strength and structural considerations of batting will be discussed in the next section.

Strength and Structural Considerations

The ability of a person to perform a motor task depends to a large degree upon that person's structure and muscular strength. Hooks investigated the relationship of 19 structural and strength measures to baseball skills (1959). He found that the structural measures had generally low correlations with baseball ability, while strength measures had high correlations. One of the skills measured was hitting ability. The subjects were 56 male college freshmen, who batted right handed. Structural measures and hitting ability were correlated as follows: upper arm girth (.50), weight of subject (.41), and hip circumference (.31). Height had no correlation with hitting ability (.06). Strength measures which correlated with hitting ability were: left shoulder flexion (.79), right wrist flexion (.66), left wrist flexion (.60) and hip extension (.60). Overall, the single best predictor for hitting ability was left shoulder flexion, and the best combined predictors were left shoulder flexion and upper arm girth (.79).

Kitzman (1964) investigated the musculature involved in baseball batting utilizing synchronized film and electromyographic recordings of upper extremity muscles. The subjects were two major league baseball players and two unskilled college freshman with no interscholastic experience in baseball. Kitzman recorded action potentials from surface electrodes of the following muscles: left and right triceps brachii--long and lateral heads, left and right latisimus dorsi, and left and right pectoralis major, clavicular head. The subjects were all right handed and batted off of a batting tee at hip height for all experimental trials. Kitzman found that peak recordings of skilled subjects appeared earlier in the swing than for unskilled subjects in all muscles measured. In fact, the skilled subjects showed a marked decrease in all action potentials once bat movement started. He concluded that skilled batters allowed body rotation and momentum to do most of the work once the swing was initiated, until wrist adduction prior to contact (wrist action potentials were not recorded). The skilled subjects had higher action potentials for the left pectoralis major than unskilled subjects, and all subjects had the highest action potentials recorded for the long head of the triceps brachii. Kitzman concluded that strengthening the long head of the left triceps brachii (for right handed hitters) would best improve the force batters could transfer to the bat.

With these two studies in mind, it is useful to consider the structural and muscular strength differences between males and females, since both groups were subjects in this batting investigation. Structurally, females have broader and shallower pelvises, lower centers of gravity, and narrower shoulders than males. Overall, muscular strength of females at maturity is approxiamately 50% of their male counterparts. Females have less muscular strength proportionate to their body mass than males: 36% versus 43%, respectively (Klafs and Arnhein, 1977). Rasch and Burke (1978) reported that females have 55% of the upper body strength of males in isometric contractions, with higher percentages reported for the trunk (66% of male strength) and the lower extremities (70%). Brouha (1962) also reported dramatic strength differences between girls and boys after puberty. Widmore (1975) found that college age females were 43 to 63 percent weaker than college age males in upper body strength, but only 27% weaker in the lower body. These findings are consistent with the generally accepted belief that females are weaker than males, especially in the upper body. Since previously cited researchers have correlated upper body strength and bat speed and effective hitting in male batters, one should expect differences in the batting abilities of males and females. The research on female batters is presented next.

Female Softball Batting

One of the earliest studies done with female subjects attempted to correlate softball skills tests with judged ratings of player ability. Fox and Young (1954) utilized a batting tee in their test of softball hitting ability. The subjects hit for distance off of a tee within fair ball markers. Batters were scored independently by judges watching the subjects hitting in game situations. The researchers found that the subjects' ability to hit for distance off of a batting tee correlated fairly highly with the judges' ratings (.64).

Messier and Owen (1982) confirmed that stride direction had no relationship to bat velocity in female collegiate softball batters. Like previous research with male subjects (Cece, 1975), there were no differences in bat velocity using open, closed and parallel stances. Both Hay (1978) and Pike (1974) have found that power hitters, who tend to have higher bat velocities, use a closed stance. In light of these studies, Messier and Owen concluded that "when female subjects utilize the closed striding method, the greater amount of muscular effort required to rotate forward does not result in a significant increase in bat velocity." This may be due to strength factors previously mentioned, or time constraints.

Three remaining studies of female softball batters investigated bat dynamics of collegiate and amateur softball players hitting balls from pitching machines. Messier and Ward (1981) examined the three-dimensional components of linear bat velocity and the kinetic energy patterns of the bat during the swing of female batters, and compared their results with previous research done with male batters (Shapiro, 1979). They found velocity and kinetic energy patterns similar to Shapiro's male batters, but of lesser magnitudes. Messier and Ward's female collegiate batters had an average maximum linear bat velocity of 17.11 ms-1 at the bat center of mass, while Shapiro reported average maximum linear bat center of mass velocity of 30.29 ms-1. The females averaged 135.1 joules for maximum kinetic energy of the bat, considerably less than Shapiro's findings of 515.8 joules for males. Messier and Ward reported maximum linear velocity and kinetic energy of the bat occurred 30ms before contact for females; this finding is similar to that of many baseball researchers previously mentioned.

In 1984, Messier and Owen further documented bat dynamics of eight female softball batters. All batters were right handed, used the same bat, and hit against a pitching machine using a parallel stance. Maximum linear velocity of the center of mass of the bat was lower than previously reported values for males (mean value was 19.08 ms-1), although one female did reach 32.87 ms-1 in one trial. Subjects achieved maximum bat velocity 32ms prior to ball contact. Messier and Owen related their findings to decreased response time and weaker musculature of female softball batters. They concluded that the combination of decreased response time and slower bat velocities for women indicated that there "may be a difference in optimal baseball and softball batting techniques."

Most recently, Messier and Owen (1985) studied the ground reaction forces and selected lower extremity kinematics of seven right handed female softball batters. The subjects were current or former collegiate softball players who were considered to be above average hitters by their coaches. A pitching machine delivered balls to the subjects who stood on a wooden hitting platform with a force plate incorporated into the center. Four trials of each subject were analyzed using synchronized three-dimensional cinematographical and force plate data. Two trials from each subject were analyzed with the rear foot starting on the force plate, and two trials with the lead foot stepping forward onto the force plate during the stride. Analysis of the force and film data was utilized to describe the lower extremities during the swing. Forces in the vertical plane represented the transfer of weight from the rear foot during the stride to the lead foot as it planted .18 seconds prior to impact. During the initial stance, a mean vertical force of .7 body weight (BW) was recorded for the rear foot, which increased to 1 BW during the stride when the lead foot was off the ground and moving forward. At lead foot plant, the weight shifted forward to the front foot, and at impact vertical forces were .43 BW and 1.5 BW for the rear and lead foot, respectively. Mediolateral forces for the rear foot were approximately .4 BW away from the pitch during the swing, and the lead foot reached a maximum of .76 BW toward the pitch at impact. Thus, the two feet pushed in opposite directions after the lead foot planted to produce forceful hip rotation during the swing.

Summary

The research reviewed in this investigation has presented a fairly consistent description of the mechanics of baseball batting. The batter chooses a comfortable stance and strides from 3 to 14 inches toward the pitcher, keeping the body center of gravity level and cocking the hip inward. After foot plant, the swing is initiated by forceful rotation of the hips, shoulders, arms and bat in a horizontal plane. Maximum bat linear velocity is achieved at contact (ideally) or immediately prior, as the extended left arm brings the bat around perpendicular to the pitch, and left wrist adduction occurs. At contact the wrists are firm, arms and left knee are extended. The batter attempts to impart maximum linear velocity to the batted ball in the desired direction. Left shoulder strength is associated with increased bat velocity.

The mechanics of softball batting are not nearly so well understood. Few researchers have utilized women as subjects, and none have compared males and females in the same study. Women batters are less powerful than men, have lower linear bat velocities and a shorter response time available to them in game situations than baseball batters. There is much to be learned about the mechanics of female softball batting relative to baseball batting. The tasks and performers are not identical, and therefore may not have the same mechanics for optimal performance. Research needs to separate which mechanical differences are attributable to sex of subject, and which are task related.

CHAPTER 3

METHOD

The procedures of this investigation are presented in this chapter. All pertinent data on subjects, task, data collection, equipment and calibration, variables measured and statistical analysis of the resultant data are included.

Subjects

The subjects for this investigation were six female intercollegiate varsity softball players and six male intercollegiate varsity baseball players. All subjects were right handed and were judged by their coaches to be consistent, effective hitters. The female subjects had a mean height of 165.52 centimeters, and a mean weight of 61.44 kilograms. The male subjects' mean height was 180.13 centimeters, and male mean weight was 79 kilograms.

Task

The subjects' task was to stand on a raised batting platform and to take ten trials hitting a wiffle ball in a hard line drive off of a batting tee, using their normal swing pattern. All subjects hit right handed using a parallel stance and provided their own bats.

Procedure

The subjects arrived at the testing station wearing tight white t-shirts, and gave their bat to the experimentor for measurement and marking. The subjects were marked and allowed to practice in the testing situation. When the subject was comfortable in the testing situation, the data collection began. The batting tee was adjusted to hip height. The batter was told to attempt to hit the ball hard and straight up the middle. An experimentor and the subject independently rated each hit on a scale from 1 to 10. Each trial followed the same format. The subject stood on the raised batting box and looked toward the imaginary mound, where an assistant stood holding a ball. The batter assumed a parallel stance in accordance with a taped line down the middle of the batter's box and force platform, which it incorporated. The batter signalled his/her readiness, and the camera and force platform recordings began. When the assistant heard the camera rolling, he dropped the ball he had held extended in his right hand. The batter watched the assistant, and began the swing when the ball was released. Force and film data were recorded for 10 trials for each subject.

All trials were filmed at 100 frames per second using a Locam 16 mm pin registered camera mounted on the ceiling 12 feet above bat level during the swing. A horizontal distance reference was filmed at tee level prior to the trials. Additional lighting was provided by three 1000 watt lights. The force platform (Hearn, 1966) contained six linear variable differential transformers which outputted electrical signals proportional to the amount of applied force or torque to three chart recorders; one each for lateral force, vertical force and twist torque. A mirror was placed along the side of the force platform in the camera's field of view and tilted approximately 45 degrees to allow the camera to see foot strike on the platform for the purpose of synchronization (see Figures 1 and 2 for experimental set up diagrams). Subject and sequence markers were included in the field of view.

Subject Markings

All subjects wore white, and were marked with half-inch black tape and/or black paint in several locations to improve accuracy in locating joint centers. The shoulder was marked with an "x" which intersected just medially of the acromium. The elbows and wrists were marked with a ring of black tape around the joint. The first metacarpal joint of the third finger of the left hand and the third metacarpal joint of the third finger of the right hand were marked with black paint. The subjects wore two nylon belts; one around the hips and the other around the chest. The hip belt had a "v" shaped projectile which protruded posteriorly in a horizontal plane at the subject's hip level. The chest belt had a straight projectile which protruded posteriorly in the horizontal plane. When viewed from above with the subject in the anatomic position, the chest projectile intersected the v shaped hip projectile below it (see figure 1). The projectiles were black with white tape markings to assure visibility. These belts were modified from Atwater

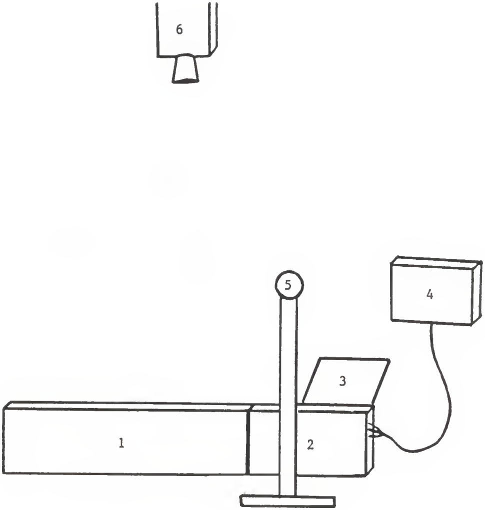

Figure 1. Overhead View of Experimental Set Up.

1., raised batting platform; 2., force platform; 3., side view mirror; 4., chart recorders; 5., top of subject's head; 6., bat COM; 7., bat COP; 8., trunk projectile; 9., hip projectiles; 10., left shoulder; 11., right shoulder; 12., right elbow; 13., right wrist; 14., left wrist; 15., ball on batting tee.

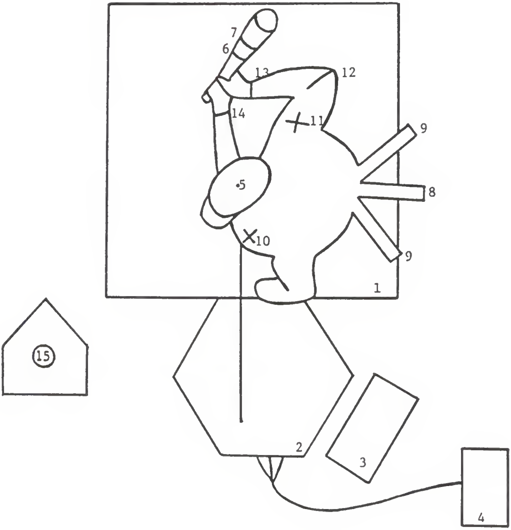

Figure 2. Side View of Experimental Set Up.

1., raised batting platform; 2., force platform; 3., side view mirror; 4., chart recorders; 5., ball on batting tee; 6., camera.

(1970) and were used to provide information on hip and thorax rotational position.

Bat Measurements and Markings

The subjects' bats were marked and measured in the following manner. The female subjects used two bats; five used a black aluminum bat, and one female used a white aluminum bat. The males also brought two aluminum bats, one white and one black. All bats were weighed, and balanced on a knife edge to determine the center of mass, which was marked with a ring of contrasting (black or white) tape. The location of the center of mass was recorded as the distance in centimeters from the impact reaction axis (d_1). The impact reaction axis was located under the first finger of the right hand. Male impact reaction axis was assumed to be 16.8 cm from the knob end (Noble, 1985), and the female reaction axis was measured by the experimentor (17.5cm). The swing axis was measured between the hands on the bat (Eggeman and Noble, 1985), and was 4.8 cm less than the reaction axis for males, and 4.4 cm less for females (swing axis is d_2). Both axes were measured from the knob end of the bat.

The center of percussion (q) of the bat was determined by swinging the bat as a pendulum at the reaction axis and timing the period (T) of the swing. Center of percussion is then equal to $(24.83877)T^2$ (Noble,1985). The moment of inertia (I) was calculated by the formula $(24.83877)T^2mr$; m is equal to mass in kilograms and r is equal to the distance in centimeters from the center of mass to the reaction axis (d_1). The parallel axis theorem was then used to calculate moment of inertia relative to the swing axis (d_2). Radius of gyration (K) was calculated from the moment of inertia of the swing axis (Id_2), from the formula $I = mK^2$. This system for bat measurement was described by Noble and Eck (1986). The results of these measurements are presented in Table 1. The center of percussion was marked with a ring of contrasting tape for filming.

Trial Rating Scale

Each trial was rated by the experimentor on a scale from 1 to 10, ten being the highest. In addition, after the experimentor rated each hit, the subject independently rated the trial on the same scale. The three trials with the highest combined rating score were selected for analysis for each subject. The scale ranged from a complete miss (1) to a short pop fly (3), a slow grounder (5), or a hard line drive up the middle (10). The complete scale follows.

1--miss	6--hard foul ball
2--slow foul ball	7--hard ground ball
3--short pop foul	8--medium line drive
4--pop up to infield	9--hard line drive
5--infield ground ball	10--hard home run ball

Calibration of the force platform

The force platform was calibrated using a spring scale

Table 1. Bat specifications.

Variable	Female Bats: Black	Female Bats: White	Male Bats: Black	Male Bats: White
Period of swing (s)	1.45875	1.4405	1.4763	1.4727
Mass (kg)	.768	.978	.903	.858
Location of impact reaction axis (cm)	32.8	32.5	33.8	39.8
Location of swing axis (cm)	37.2	36.9	38.6	44.6
Location of center of percussion (cm)	52.856	51.54	54.14	53.87
Moment of inertia, reaction axis ($cm\text{-}kg^2$)	1331.5	1638.2	1652.3	1839.6
Moment of inertia, swing axis ($cm\text{-}kg^2$)	1567.9	1936.9	1999.9	2187.2
Location of radius of gyration (cm)	45.18	44.5	47.06	50.49

attached to a cable and known weights. Vertical force was calibrated with a 100 pound weight. Lateral force was calibrated with the spring scale pulling a known force of 9 kg in the lateral plane. Twist torque was calibrated with a known force in the lateral plane a known distance from the center axis of the platform. Pen deflection in millimeters for each of the calibration forces was recorded and labelled. Conversion factors were then calculated for each of the three variables measured with the force platform. Peak amplitude of the force-time and torque-time curves were recorded for all trials.

Variables Measured

The following measurements were made during this investigation: subject gender, weight (kg) and height (cm), maximum linear and angular velocity and acceleration of the center of percussion of the bat; linear and angular velocities and accelerations of the hip, trunk, shoulder, left arm, left forearm and left wrist; position of the left elbow at impact; ground reaction forces of the lead foot during the swing in the lateral and vertical planes, and torque about the vertical axis (twist torque).

Equipment

1) Force Platform. Kansas State University LVDT force platform was used in conjunction with three chart recorders.
2) Batter's Box Platform. A raised plywood platform served

as the batter's box. It was 4' x 4' x 7'', and was level with the top of the force platform.

3) Camera. A 16 mm Locam pin registered camera was used with a 100 mm lens. The camera was mounted on a tripod attached to the ceiling beams.

4) Batting Tee. Kansas State University Athletic Department batting tees were used. They were adjustable in height.

5) Balls. Plastic baseball-sized wiffle balls were used.

Statistical Analysis

The male and female data were analyzed using three trials per subject. The mean value for each subject was calculated, and group comparisons were made using paired t-tests. The peak value of each variable, and the time that the peak value occurred relative to impact were compared to determine if significant differences existed between male and female subjects.

CHAPTER 4

RESULTS

The film and force data were analyzed to describe selected kinetic and kinematic parameters of the swing with respect to males and females, and to determine if significant differences existed between the two groups. The results of each variable are presented in this chapter in the sequence in which they occur in the execution of the movement, beginning with the lead foot forces and working up the body to the bat movement parameters. This sequence was previously described in Chapter Two as the kinetic link (Krieghbaum and Barthels, 1985). Furthermore, the results section is subdivided into two parts. The first part presents the peak value of each kinetic and kinematic variable so that differences in magnitude between the groups can be determined. The second part addresses the sequencing of each variable's peak value during the swing so that timing differences between the populations can be evaluated. All significant differences discussed in the text are at $p < .01$ unless otherwise stated. Group means, standard deviations (S.D.), and p values of group comparisons for all variables are presented in Table 2 (magnitude), and Table 3 (timing).

Kinetic and Kinematic Magnitudes

The peak values of the lead foot force and torque data were divided by body weight for each subject to eliminate differences due to subjects' mass, and group means for males and females were compared. The mean peak vertical force was 1.2325 body weight (BW) for female subjects (S.D.=.736 BW), and 1.5038 BW for male subjects (S.D.=.162 BW). Mean peak lateral forces (toward the pitcher) were .3333 BW for females (S.D.=.096 BW) and .4007 BW for males (S.D.=.089 BW). Mean peak twist torque about the vertical axis for females was .0365 BW, and .0419 BW for male subjects (S.D.=.0165 BW and .00496 BW, respectively). The males had greater force and torque values in all cases, although none of these means were significantly different. The female subjects had consistently higher standard deviations than males.

The next two selected variables in the sequence involved movement of the subjects' hips: (1) maximum hip angular velocity (HIP MAX AV), and (2) the range of hip angular displacement (HIP ANG DIS) from lead foot contact to ball contact. Female subjects' mean MAX HIP AV was 22.702 radians per second (rs-1), and male MAX HIP AV was 25.3097 rs-1 (S.D.=1.625 and 3.699 rs-1, respectively). The male value was not significantly higher than the female. Mean HIP ANG DIS was similar for both groups; 179.875 +/- 20.342 degrees (dg) for females versus 183.1 +/- 24.38 dg for males. Trunk movement was analyzed using the same two measurements as for the hips. Average MAX TRUNK AV for female subjects (12.3325 rs-1) was significantly slower than for male subjects (17.3298 rs-1). TRUNK ANG DIS was significantly less ($p<.05$) for females (96.967 dg) than for

Table 2. Group comparisons of peak kinetic and kinematic parameters.

VARIABLE MEASURED	FEMALE MEAN	FEMALE S.D.	MALE MEAN	MALE S.D.	P <
VERTICAL FORCE (BW)	1.2325	.736	1.5038	.162	
LATERAL FORCE (BW)	.3333	.096	.4007	.089	
TWIST TORQUE (BW)	.03565	.01065	.0419	.00496	
MAX HIP AV (rs-1)	22.702	1.625	25.309	3.699	
HIP ANG DIS (dg)	179.875	20.342	183.1	24.38	
MAX TRUNK AV (rs-1)	12.3325	1.925	17.329	2.803	.01
TRUNK ANG DIS (dg)	96.967	13.022	112.452	8.153	.05
L.ARM MAX LV (ms-1)	2.941	.412	3.687	.405	.02
L.FOREARM MAX LV (ms-1)	5.3425	.811	7.087	.761	.01
L.HAND MAX LV (ms-1)	7.735	1.013	9.8325	1.087	.01
L.ELBOW POS IMP (dg)	14.561	7.16	31.707	5.56	.01
BAT COM MAX LV (ms-1)	17.494	1.046	22.182	1.155	.01
BAT COM MAX LA (ms-2)	685.787	132.78	981.923	101.13	.01
BAT COP MAX LV (ms-1)	32.568	2.478	38.424	1.545	.01
BAT COP MAX LA (ms-2)	685.787	132.78	981.923	101.13	.01
BAT MAX AV (rs-1)	35.5405	4.11	43.885	2.58	.01
BAT MAX AA (rs-2)	307.27	22.074	458.775	58.15	.01

males (112.451 dg). Females' trunk angular velocity and displacement were less than male subjects.

The left arm, forearm and hand mean maximum linear velocities (LV) for males and females were compared next. The mean left arm maximum linear velocity (L. ARM MAX LV) was significantly slower ($p<.02$) for females (2.941 ms-1) than for males (3.687 ms-1). Mean L. FOREARM MAX LV for females was 5.3425 ms-1, and was also significantly slower than the males' mean value of 7.087 ms-1. L. FOREARM MAX LV represented a difference in speed of 2.4 ms-1 for females, and 3.4 ms-1 for males over their respective L. ARM MAX LV values. This pattern continued with the left hand. Female mean L. HAND MAX LV was 7.735 ms-1, which represented a difference of approximately 2.4 ms-1 over female L. FOREARM MAX LV. Male mean L. HAND MAX LV (9.8325 ms-1) was significantly faster than the female value, and was approximately 2.75 ms-1 faster than male L. FOREARM MAX LV.

The subjects' left elbow position at impact (L. ELBOW POS IMP) was found to be significantly different between groups. The female subjects' mean elbow position was 14.561 dg at impact, while the males' L. ELBOW POS IMP was 31.707 dg on the average. These values represent the acute angle from a fully extended elbow position of 180 dg (0 dg would be perfectly straight).

The final area of comparison between the two groups was the bat movement parameters. Group means for bat linear velocity, linear acceleration (LA), angular velocity, and angular acceleration (AA) were calculated for the duration of the swing, and are presented in Figures 3-6. The patterns are very similar for males and females with the males having higher peak values in all cases. Timing differences between the patterns of the four bat variables throughout the swing will be discussed in the next section.

Linear velocity and linear acceleration of the bat were measured at the bat center of percussion (COP), as previously described in Chapter Three. However, for purposes of comparision with other studies, linear velocity and acceleration was also measured at the bat center of mass (COM). Mean BAT COM MAX LV was 17.494 ms-1 for females, and 22.182 ms-1 for males. Mean BAT COM MAX LA was 377.888 ms-2 and 555.504 ms-2 for females and males, respectively. For group comparisons, mean BAT COP MAX LV and BAT COP MAX LA values were used.

Specifically, mean BAT COP MAX LV was 32.568 ms-1 for females and 38.4524 ms-1 for males, with the male batters significantly faster than the female batters. Linear acceleration of the bat COP was also significantly higher for males than females (F= 685.787 ms-2, M= 981.923 ms-2). Finally, the male subjects' bat angular velocity and acceleration were significantly higher than the females. Male mean BAT MAX AV was 43.885 rs-1 compared to 35.5405 rs-1 for females, and mean BAT MAX AA was 458.775 rs-2 versus 307.27 rs-2 for males and females, respectively.

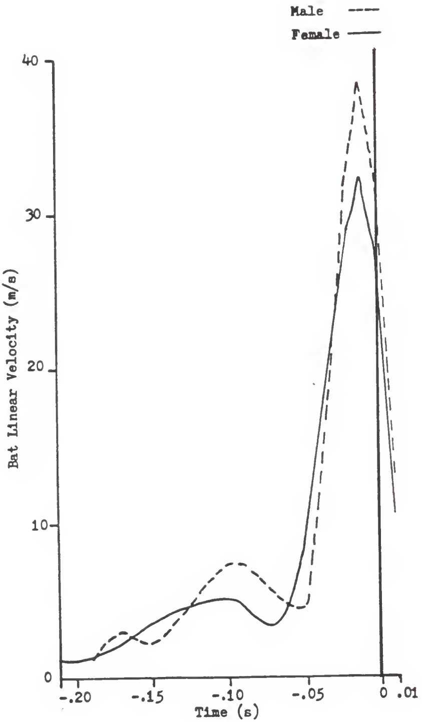

Figure 3. Bat Resultant Linear Velocity

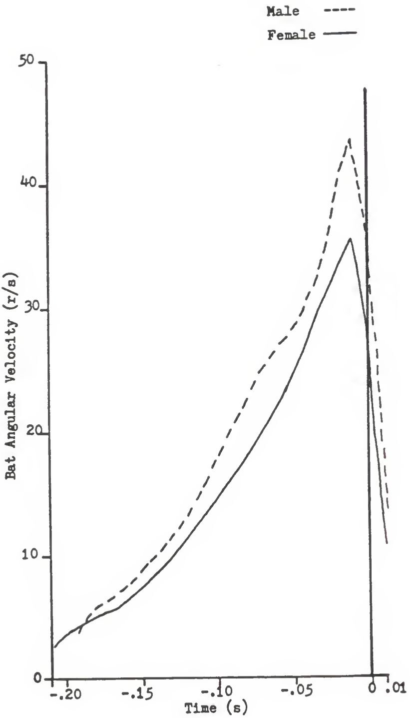

Figure 4. Bat Resultant Angular Velocity

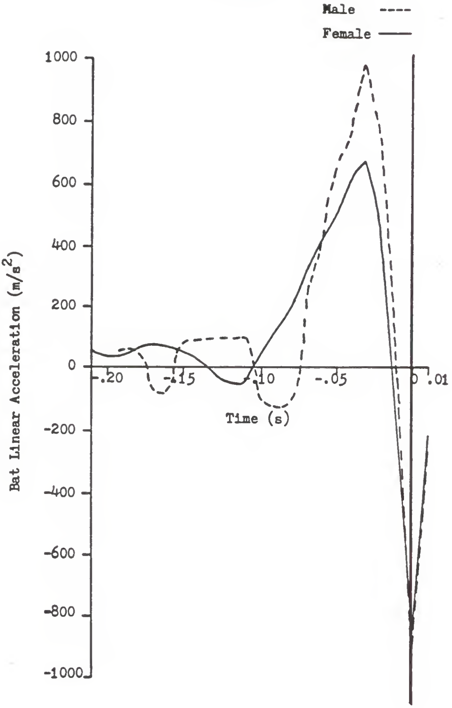

Figure 5. Bat Resultant Linear Acceleration.

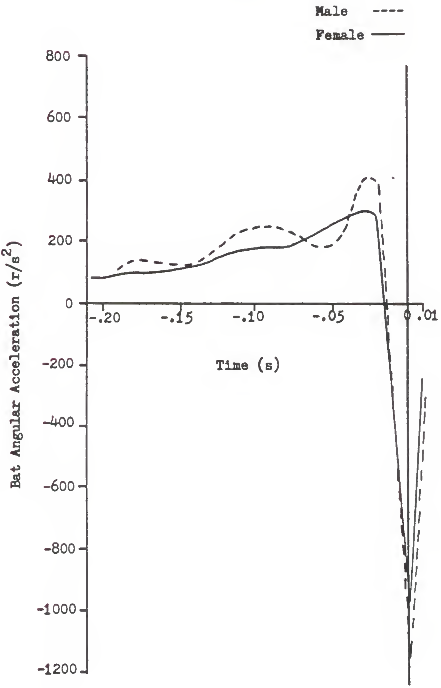

Figure 6. Bat Resultant Angular Acceleration.

Timing of Kinematic Peaks Relative to Impact

Although comparisons of the magnitudes of selected kinematic values are important, it is equally important to determine when these peak values occurred in the swing. Thus, the time prior to ball contact (time PC) was recorded for each peak kinematic variable measured, and group means were calculated for each variable's time PC. In addition, the mean total swing time for each group was compared. Total swing time was defined as the time from the initial movement of the bat forward toward the ball to impact of the bat and ball. The males' mean swing time was significantly shorter than the females' mean swing time, which was expected in light of the slower bat linear velocities of the female subjects. The average male swing time was .1871 seconds (s) (S.D.= .0201s), and the average female swing time was .2283s (S.D.= .0182s). The females took an average of .041s longer to swing the bat than the males.

Differences beyond overall duration in the timing pattern between males and females were found. The sequence in which different body segments reached their respective peak velocities also differed between male and female subjects. Males reached MAX HIP AV at an average of .0959s PC, and MAX TRUNK AV at the mean time of .0767s PC, roughly

their MAX HIP AV and MAX TRUNK AV almost simultaneously. Females' MAX HIP AV occurred at an average of .0736s PC, which is significantly later in the swing than male MAX HIP AV ($p<.02$). Female MAX TRUNK AV occurred at a mean of differences also existed between the time PC of the left arm segment maximum linear velocity for males and females. The L. ARM MAX LV mean time PC was .0733s for males, and .0967s for females. Thus, the males' hip, trunk, left arm sequence of maximum velocities followed the kinetic link model, and occurred at mean times of .0959s, .0767s and .0733s PC, respectively. The females' hip, trunk and left arm sequence was different from the males' sequence and the kinetic link model, with average values of .0736s, .0706s, and .0967s PC, respectively. The hip and left arm times were significantly different for the two groups.

Male and females were very similar in the mean time of L. FOREARM MAX LV (.064s and .0645s PC, respectively), L. HAND MAX LV (.054s and .0567s PC), BAT COP MAX LV (.01s PC for all subjects) and BAT COP MAX LA (.0312s and .0308s PC, respectively). The only other group difference occurred in the bat angular data. While BAT MAX AV occurred at .01s PC for all subjects, BAT MAX AA occurred significantly earlier in the swing for females (.044s PC) than for males (.0253s PC; $p<.02$). Comparing the graphic depictions of mean bat linear and angular acceleration throughout the swing (Figures 5 and 6), the females began their linear acceleration .03s sooner than the males, and reached their peak angular acceleration .0187s earlier.

Table 3. Time of occurrance of peak kinematic values relative to ball contact.

TIME OF VARIABLE*	FEMALE MEAN	FEMALE S.D.	MALE MEAN	MALE S.D.	P <
SWING TIME	.2283	.0182	.1871	.0201	.01
MAX HIP AV	.0736	.0156	.0959	.0118	.02
MAX TRUNK AV	.0706	.0191	.0767	.0116	
L. ARM MAX LV	.0967	.015	.0733	.0047	.01
L. FOREARM MAX LV	.0645	.012	.064	.0085	
L. HAND MAX LV	.0567	.0139	.054	.0049	
BAT COP MAX LV	.01	0	.01	0	
BAT COP MAX LA	.0308	.00204	.0312	.00286	
BAT MAX AV	.01	0	.01	0	
BAT MAX AA	.044	.01478	.0253	.00455	.02

* All variables measured in seconds prior to ball contact (PC)

Summary of Results

The results of this investigation indicated no significant differences between male and female lead foot forces or twist torque when expressed as subject body weight. Mean MAX HIP AV and HIP ANG DIS were also not significantly different for males and females. Male subjects had significantly higher peak linear and angular velocities and accelerations for all other segments measured (including the bat) when compared to female subjects. Females reached their maximum hip angular velocity .022s closer to impact than males did, but reached L. FOREARM MAX LV and BAT MAX AA approximately .02s earlier in the swing than male subjects. Overall, females' total swing time averaged about .04s longer than male subjects.

CHAPTER 5

DISCUSSION

The results of this investigation allow direct comparison of the mechanics of the male baseball batting swing and the female fast pitch softball batting swing. In addition, these results are compared to those of other batting studies for further interpretation. The conclusions drawn from this investigation are presented in this chapter, along with the resultant implications for practical applications to batting, and suggestions for further research.

No significant differences were found between male and female subjects' lead foot forces and twist torques, however, the males had consistently higher mean peak values with lower variability. This was especially evident in the vertical force of females, which had a standard deviation 4.5 times greater than the male value. The mean peak lateral forces for males and females were very similar in magnitude and variability, but were lower than the mean value of .76 BW reported in Messier and Owen's study of females hitting pitched balls (1985). The difference between the studies may be caused by differences in the tasks of hitting pitched balls versus hitting off of a batting tee. In addition, some lateral platform slippage occurred in this investigation. This could contribute to the lower lateral forces recorded.

There were no significant differences between male and female subjects' MAX HIP AV and HIP ANG DIS means. However, females reached their peak hip angular velocity later in the swing than males. It took the female subjects an average of 0.064s longer than males to achieve MAX HIP AV from the time of initial bat movement toward the ball. In addition, females' MAX HIP AV occurred .022s closer to impact than male subjects.

Significant differences between male and female peak segmental velocities also occurred in the trunk and left arm segments. Males reached MAX TRUNK AV approximately .02s after their hip angular velocity peaked. Subsequently, males' left arm linear velocity peaked, followed in order by the left forearm, left hand and bat. Females displayed a different sequence, and did not follow the same kinetic link model as the male subjects. The female sequence of peak velocities began with the left arm, then the hips and trunk. Females' forearm, hand and bat linear velocities each peaked in the same sequence, and at the same time prior to contact, as the male subjects. All female mean peak segment and bat velocities were significantly slower than the males' velocities, with exception of MAX HIP AV previously mentioned.

It is important to note that the female swing was not just a slower version of the male swing. It is hypothesized that the females' proportionally larger hips create larger hip moment of inertia, and therefore greater resistance to hip rotation. Thus, the females seemed to need more time than males to generate the same MAX HIP AV. Females do not have enough time left in the swing after reaching MAX HIP AV to complete the same sequence of segmental peak velocities as the males. The females in this study seemed to have solved the problem by giving their left arm a head start. Every female in each trial analyzed reached maximum linear velocity of the left arm before hip and trunk maximum angular velocity. Yet the females' forearm, hand and bat velocities peaked at times identical to the males. Thus, the crucial difference between male and female swings was the timing of peak velocities for the left arm and hips.

It is possible that the females initiated arm movement early to compensate for the late-peaking hips. Another hypothesis is that females may have difficulty holding the left arm back due to the breasts. Hip rotation causes chest rotation, which may force the left arm forward prematurely. In either case, the premature peaking of left arm linear velocity by females fails to take advantage of momentum created by peak hip and trunk angular velocity.

Ultimately, females in this study had slower bat speeds than males. However, the range of individual peak bat linear and angular means for subjects in each group overlapped. Individual female BAT COP MAX LV means ranged from 29.899 to 36.454 ms-1. Subject means for males' BAT COP MAX LV ranged from 35.839 to 40.267 ms-1. Individual means for BAT MAX AV overlapped as well, with the females ranging from 30.486 to 40.044 rs-1, and the males ranging from 39.702 to 46.771 rs-1.

The only significant timing difference between male and female bat kinematics occurred in the angular acceleration of the bat. Females reached mean BAT MAX AA .02s before males, indicating that females may straighten their elbows earlier in the swing than males. Left elbow position was measured in the frame of film immediately before and after ball contact. All subjects had fully extended elbows immediately after impact, but the females' left elbow was extended an average of 15 degrees further than males in the frame before contact. Thus, males straightened the elbow more than females in the last .01 second before impact. Early straightening of the left elbow by females may be related to the early initiation of left arm linear velocity.

The results of this investigation are comparable to those of other batting studies. McIntyre and Pfautsch (1982) found similar magnitudes and timing of peak linear velocities of males' upper extremity segments. Several studies have investigated maximum resultant bat linear velocity, but comparison between studies is dependent upon the point of the bat used to measure linear velocity. Their results, along with the results of this investigation, are summarized in Table 4.

The mechanics of college male baseball batters in this study are similar to those described in the other investigations in Table 4. Messier and Owen (1984) and Messier and Ward (1981) are the only other researchers who have investigated college females, and their results are

Table 4. Comparison of peak resultant bat linear velocities.

SOURCE	SEX OF SUBJECTS	PEAK RESULTANT BAT LV AT:		
		BAT COM	BAT COP	BAT TIP
Spragg (1986)	Male	20-23*	35-40	
Shapiro (1979)**	Male	26-34		
McIntyre and Pfautsch (1982)	Male			39-42
Spragg (1986)	Female	16-18	29-36	
Messier and Owen (1984)**	Female	19***		
Messier and Ward (1981)	Female	17		

* All values in Table 4 reported in meters per second.

** Used three dimensional resultant linear velocity.

*** Inferred from the study's methodology and discussion that researchers used COM.

comparable to the females in this investigation. Therefore, the use of a batting tee to eliminate pitching differences does not seem to have significantly affected these characteristics of the swing. Without time and accuracy limitations imposed by pitched balls, females consistently needed more time to swing the bat, with less resultant linear bat velocity than males. Females also took longer to reach peak hip angular velocity and reached left arm maximum linear velocity earlier than males. This suggests that the shorter pitching distance (and resultant time constraints) may not be the only factor limiting female bat speed.

The results of this investigation suggest that body structure, trunk and upper body strength, and technique may be responsible for the slow bat speeds of females. Group differences may be due to differences in the lean body mass of the female and male subjects, since strength has been positively correlated with lean body mass. In particular, the female batter may need to initiate hip rotation earlier in the swing, and hold the left arm back so that the left arm linear velocity peaks after hip angular velocity. An open batting stance may assist the female batter in achieving earlier hip rotation. Although each subject was consistent across trials, the high within-group variability of the female subjects compared to male subjects indicates that the skilled males were more homogeneous than the skilled females. The female subjects may have been less skilled than the males; as invariance is a well-known characteristic of highly skilled performance. Midwestern females may not have had as many opportunities to play organized ball as the males did.

Further research is indicated for female softball batting. An increased number of subjects would allow the researcher to compensate statistically for the higher variability. Further investigation of the interrelationship between hip, trunk and left arm motion parameters will provide insight regarding the most effective technique for female softball batting.

References

Atwater, A. E. (1970). Movement characteristics of the overarm throw. Unpublished doctoral dissertation, University of Wisconsin, Madison, WS.

Breen, J. L. (1967). What makes a good hitter? Journal of Health, Physical Education and Recreation, 38, 36-39.

Brouha, L. (1962). Physiology of training including age and sex differences. Journal of Sports Medicine, 2:3, 45-52.

Cece, A. T. (1975). A study to determine the relationship of stance and length of stride to bat swing velocity. An unpublished masters thesis, Springfield College, Springfield MA.

Eggeman, G. W. and Noble. L. (1985). Design and testing of a baseball-bat transducer. Experimental Techniques, 9:2, 20-23.

Fox, M. G. and Young, O. G. (1954). A test of softball batting ability. Research Quarterly, 25, 26-27.

French, L. D. (1970). A study to determine the relationships among trunk rotation strength, leg strength, and the velocity of swinging a baseball bat. Unpublished masters thesis, Springfield College, Springfield, MA.

Hay, J. G. (1978). The Biomechanics of Sports Techniques, 2nd ed. Englewood Cliffs, NJ: Prentice-Hall.

Hearn, N. K. N. Jr. (1966). Design and construction of a force platform with torque measurement capability.

Unpublished master's thesis, Kansas State University, Manhattan, KS.

Hooks, G. E. (1959). Prediction of baseball ability through an analysis of measures of strength and structure. Research Quarterly, 30:1, 38-43.

Kitzman, E. W. (1964). Baseball: Electromyographic study of batting swing. Research Quarterly, 35, 166-178.

Klufs, C. E. and Arnheim, D. D. (1977). Modern Principles of Athletic Training, 4th ed. St. Louis, MO: The C. V. Mosby Company.

Magarian, K. (1975). The relationship of bat performance time to baseball batting ability. Unpublished masters thesis, Springfield College, Springfield, MA.

McIntyre, D. R. and Pfautsch, E. W. (1982). A kinematic analysis of the baseball batting swings involved in opposite-field and same-field hitting. Research Quarterly, 53, 206-213.

Messier, S. P. and Owen, M. G. (1982). Relationships among selected kinematic parameters, bat velocities, and three methods of striding by female softball batters. AAHPERD Abstracts of Research Papers, p. 11. Reston, VA: AAHPERD.

Messier, S. P. and Owen, M. G. (1984). Bat dynamics of female fast pitch softball batters. Research Quarterly, 55:2, 141-145.

Messier, S. P. and Owen, M. G. (1985). The mechanics of batting: analysis of ground reaction forces and selected lower extremity kinematics. Research Quarterly, 56:2, 138-143.

Messier, S. P. and Ward (1981). Dynamics of female softball batters. Personal communication, Wake Forest University, Winston-Salem, NC.

Noble, L. (1985). Empirical determination of the center of percussion axis of softball and baseball bats. Biomechanics IX-B, pp. 516-520. Champaign, IL: Human Kinetics Publishers, Inc.

Noble, L. and Eck, J. (1986). Effects of selected softball bat loading strategies on impact reaction impulse. Medicine and Science in Sport and Exercise, 18, 50-59.

Pike, H. F. (1974). Cinematographical analysis of wrist and leading arm extension of two baseball batters, comparing a power hitter with a punch hitter. Unpublished masters thesis, University of North Carolina, Greensboro, NC.

Puck, P. E. (1964). Cinematographical analysis of effective batting performance. Unpublished masters thesis, Illinois State University, Normal, IL.

Race, D. E. (1961). A cinematographical and mechanical analysis of the external movements involved in hitting a baseball effectively. Research Quarterly, 32, 394-404.

Rasch, P. J. and Burke, R. K. (1978). Kinesiology and Applied Anatomy, 6th ed. Philadelphia PA: Lea and Febiger.

Ryan, J. T. (1973). A cinematographical analysis of the baseball swing. Unpublished masters thesis, Memphis State University, Memphis, TN.

Shapiro, R. (1974). Cinematographic analysis of batters hitting baseballs thrown at different heights and velocities. Unpublished master's thesis, The Pennsylvania State University, State College, PA.

Shapiro, R. (1979). Three-dimensional kinetic analysis of the baseball swing. Unpublished doctoral dissertation, University of Illinois at Urbana-Champaign.

Williams, T. and Underwood, J. (1968). Hitting was my life: part V--the science of batting. Sports Illustrated, 29, 41-52.

Wilmore, J. H. (1975). Inferiority of female athletes: myth or reality. Journal of Sports Medicine, 3:1, 62-68.

APPENDIX A

Subject Orientation

Thank you for participating in this investigation. The purpose of this research is to compare certain mechanical factors in male baseball and female fast pitch softball batting. You will be asked to take ten hits, trying to hit solid line drives up the middle. You will be using your own bat and hit wiffle balls off of a batting tee. The batter's box is a raised platform in this experiment so that a force platform can be incorporated into the front end of the batter's box. This is so that your lead foot will stride onto the force platform naturally during the swing.

In addition, you will be filmed by an overhead camera during your trials at bat. To help us use the film to measure certain movements, you will be marked with reflective tape at the shoulders, elbows and wrists. Your bat will also be marked with two rings of tape. Finally, you will be asked to wear two belts with markers protruding backwards. These will enable the camera to moniter hip and trunk rotation.

You will be allowed time to practice and get used to the testing situation. If you have any questions during the testing, please ask me. This research is part of my thesis requirement for a master's degree in Physical Education. All data and film will be kept confidential, but you will be able to see your own film trials and data if you request. A follow up letter will be sent to you when the research is completed, detailing the results. I am hoping to describe and explain the similarities and differences between the male baseball swing and the female softball swing.

Thank you for your cooperation and assistance.

If you have any questions or concerns, contact:

Carolyn Spragg, Researcher
C-13 Edwards Hall or Rm 9A Ahearn
532-5573 532-6765

Dr. Larry Noble, Faculty Advisor
532-6765

APPENDIX B

Informed Consent

A Comparison of Selected Mechanical Factors in Male Baseball and Female Fast Pitch Softball Batters.

1. I,________________ volunteer to participate in a project in connection with research studies to be conducted by Kansas State University.

2. I fully understand the purpose of the study as outlined in the attached orientation statement.

3. I also understand that I am a volunteer for this research, and that I may decline to participate. I further understand that I will be permitted to leave the test at any time and I may discontinue participation.

4. I understand that my performance as an individual will be treated as research data and will in no way be associated with me other than for identification purposes, thereby assuring anonymity of my performance and response.

5. If I have any questions concerning my rights as a test subject, injuries resulting from my participation, or any questions concerning the study, I understand that I can contact Carolyn Spragg (532-5573/6765).

I have read the Subject Orientation statement attached, and signed the herin Informed Consent statement, this ______ day of __________, 19___. ______________________________

APPENDIX C

Female Subjects' Individual Data

Variable (units)	Female Subjects' (F1-F6) Mean Data					
	F1	F2	F3	F4	F5	F6
HEIGHT (cm)	165.1	172.7	170.2	167.6	157.5	160
WEIGHT (kg)	59.1	63.6	61.4	59.6	63.6	61.4
VERTICAL FORCE (BW)	1.465	1.719	1.969	.279	.334	1.629
LATERAL FORCE (BW)	.443	.278	.412	.218	.248	.401
TWIST TORQUE (BW)	.0259	.0228	.0457	.0379	.0494	.0322
SWING TIME (s)	.2167	.21	.24	.2133	.233	.2567
BAT COP MAX LV (ms-1)	33.02	30.45	36.45	29.89	34.15	31.44
BAT COP MAX LA (ms-2)	719.9	641.6	751.4	508.5	891.4	601.8
TIME PC of " " (s)	.03	.03	.03	.03	.03	.035
BAT MAX AV (rs-1)	37.72	34.01	39.46	31.52	40.04	30.49
BAT MAX AA (rs-2)	307.3	306.8	307.6	326.5	328.7	267.2
TIME PC of " " (s)	.057	.03	.065	.047	.03	.035
L.HAND MAX LV (ms-1)	9.38	6.62	7.58	7.91	8.16	6.76
TIME PC of "" (s)	.06	.063	.06	.047	.075	.035
L.F.ARM MAX LV (ms-1)	6.57	4.76	4.77	5.61	5.87	4.48
TIME PC of " " (s)	.057	.063	.08	.047	.07	.07
L.ARM MAX LV (ms-1)	3.58	2.35	2.72	2.89	3.14	2.96
TIME PC of " " (s)	.12	.09	.10	.08	.105	.085
L. ELBOW POS IMP (dg)	24.19	21.46	12.59	4.65	13.42	11.04
MAX TRUNK AV (rs-1)	12.87	9.61	13.31	11.89	15.19	11.11
TIME PC of " " (s)	.095	.072	.09	.045	.06	.062
MAX HIP AV (rs-1)	23.35	19.98	23.17	21.79	24.73	23.18
TIME PC of " " (s)	.082	.072	.06	.052	.095	.078
TRUNK ANG DIS (dg)	110.2	84.12	98.45	79.67	111.3	98.06
HIP ANG DIS (dg)	195.9	153.0	191.6	154.6	195.0	189.2

APPENDIX D

Male Subjects' Individual Data

Variable (units)	Male Subjects' (M1-M6) Mean Data					
	M1	M2	M3	M4	M5	M6
HEIGHT (cm)	173.9	185.4	175.3	175.3	180.3	190.5
WEIGHT (kg)	65.9	86.4	74.1	77.3	75	95.4
VERTICAL FORCE (BW)	1.41	1.39	1.61	1.69	1.62	1.28
LATERAL FORCE (BW)	.438	.374	.468	.502	.253	.369
TWIST TORQUE (BW)	.0469	.0375	.0429	.0442	.0455	.0342
SWING TIME (s)	.183	.203	.17	.187	.217	.163
BAT COP MAX LV (ms-1)	39.37	40.27	37.56	35.84	38.79	38.71
BAT COP MAX LA (ms-2)	895.2	820.1	1027	1080	1026	1042
TIME PC of "" (s)	.03	.037	.03	.03	.03	.03
BAT MAX AV (rs-1)	44.06	39.70	46.77	44.13	42.44	46.20
BAT MAX AA (rs-2)	491.2	387.8	488.4	531.4	390.7	463.1
TIME PC of "" (s)	.03	.025	.03	.02	.02	.027
L.HAND MAX LV (ms-1)	8.59	8.59	9.66	10.24	10.68	11.22
TIME PC of " " (s)	.05	.057	.06	.053	.057	.047
L.F.ARM MAX LV (ms-1)	6.18	6.20	6.94	7.67	7.84	7.69
TIME PC of " " (s)	.067	.067	.077	.053	.063	.057
L.ARM MAX LV (ms-1)	3.40	3.68	3.71	4.42	3.68	3.24
TIME PC of " " (s)	.07	.073	.067	.073	.08	.077
L. ELBOW POS IMP (dg)	38.99	27.98	23.46	35.74	33.23	30.84
MAX TRUNK AV (rs-1)	18.3	20.39	14.27	20.25	16.71	14.06
TIME PC of " " (s)	.065	.087	.092	.065	.082	.07
MAX HIP AV (rs-1)	24.66	20.01	24.34	25.14	31.49	26.22
TIME PC of " " (s)	.105	.092	.112	.082	.085	.10
TRUNK ANG DIS (dg)	112.4	106.8	100.3	123.9	115.9	115.4
HIP ANG DIS (dg)	183.9	144.5	176.6	178.8	218.3	196.4

A COMPARISON OF SELECTED MECHANICAL FACTORS IN MALE BASEBALL AND FEMALE FAST PITCH SOFTBALL BATTING

by

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B.S., University of Delaware, 1983

AN ABSTRACT OF A MASTER'S THESIS

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The purpose of this investigation was to compare selected mechanical factors in male baseball and female softball batters. Six female intercollegiate varsity softball players and six male intercollegiate varsity baseball players volunteered as subjects for this study. The subjects hit a wiffle ball off of a batting tee at hip height. Subjects were filmed from overhead at 100fps and lead foot forces were recorded with a LVDT force platform. The best three trials out of ten recorded were analyzed for each subject. Group means for males and females were compared. The results of this investigation indicated no differences between male and female lead foot forces or twist torque when expressed as subject body weight. Males had significantly higher peak linear and angular velocities for all body segments measured, except for hip angular velocity. Females reached peak segmental velocities in a different sequence than males, who followed the kinetic link model. Males' hip, trunk and left arm peak velocities occurred at mean times of .0959s, .0767s and .0733s prior to ball contact (PC). The females' sequence was left arm (.0967s PC), hip (.0736s PC) and trunk (.0706s PC). Mean male bat maximum linear velocity at the center of percussion was significantly faster than for females (male x = 38.42 +/-1.545 ms-1; female x = 32.57 +/-2.478 ms-1). The bat kinematics followed similar patterns and magnitudes as reported by other researchers. Further study of females' hip, trunk and left arm movement parameters is recommended.