Analysis of Softball Pitching

Marion J.L. Alexander, PhD.
Carolyn Taylor, MSc
Sport Biomechanics Laboratory
Faculty of Kinesiology and Recreation Management
University of Manitoba

Softball Pitching Technique

Softball pitching is the most important skill in the game of softball, as the pitcher can dominate the game as no other player is able to do. Softball is usually a low scoring game in which only one or two runs are scored during the entire game, often due to the dominance of a highly skilled pitcher. Pitchers require several years to perfect their technique and gain control over the speed and direction of their pitches. Softball pitchers use an underhand motion that is not as stressful to the shoulder joint as the overhand pitch used in baseball. Softball pitchers can often pitch several games in one day, and often have an extended career of many years due to the lower stress levels on the shoulder joint. A softball pitcher may pitch as many as six 7-inning games during a weekend tournament; and often the best pitcher on a college team pitches most, if not all of the games each season (Werner, Guido et al. 2005). This may result in approximately 1200-1500 pitches being thrown in a 3-day period for a windmill pitcher, as compared to 100-150 for a baseball pitcher (Werner, Guido et al. 2005).

The softball pitch is a relatively simple motion, consisting of a step forward from the mound onto the foot on the non pitching arm side, weight shift onto this foot, and rotation of the shoulders and trunk to a position facing the batter. The pitching arm movement follows the rotation of the trunk, and is produced by forceful shoulder flexion, medial rotation and lower arm pronation during release. Skilled softball pitchers can release the ball at a speed of 55 miles/hour, or 25 m/s. Previous studies have reported an average release speed of 25.83 m/s, and a range of 23.7 m/s to 27.7 m/s (Werner 1994).

This may be compared to the high speed fastball in baseball pitching, which can be released at over 100 m/h, or 45 m/s. The ball velocity at release is one of the most important aspects of pitching skill.
especially as it relates to injury to the throwing arm. It has been reported that although softball pitchers may experience fewer injuries to the pitching arm, both types of pitchers experience distraction forces that are equal to body weight or higher on the shoulder joint [Alderson, 1999 #81; Werner, 1995 #23;].

**Preliminary position**

The pitcher must begin the pitch in a position with both feet in contact with the pitching rubber, and both hands on the ball and must pause for at least one second prior to delivery of the ball. The shoulders must be square to home plate and the ball held in the midline of the body. The ball is gripped near the ends of the fingers with the fingers on the seams. The specific grip is determined by the type of pitch being thrown and varies with the pitch (Regitano 1982). The pitch begins when the hands separate and the pitching arm moves back to a position behind the body.

It is important to differentiate between the back leg and the front leg of the pitcher. The back leg is the leg from which the pitcher pushes off during the pitch- this leg starts on the pitching rubber and often slides forward from the mound during the pitch. This leg is also called the pivot foot or the pitching foot, and is the right foot for a right handed pitcher so is the foot on the same side as the pitching arm. The front leg is the leg onto which the weight is shifted during the pitch, also called the stride leg. A long step is taken onto the stride leg during the pitch, and all the weight is shifted onto this leg as the ball is delivered. This is the left foot for a right handed pitcher; or the non pitching leg.
In the stance phase the pitcher should assume a wide stance with both feet touching the rubber but as far apart as possible. This wide stance allows the pitcher to build up momentum over a greater distance than a narrower stance (Kirby 1969). The feet are placed about shoulder width apart in the lateral direction.

**Backswing**

The backswing begins as the pitching arm moves backward, a movement known as shoulder extension, which places the anterior shoulder muscles on a stretch prior to the forceful delivery motion (Figure 3). This movement is often accompanied by trunk flexion, which places the back extensor muscles on a stretch prior to back extension during the delivery. As the arm moves back, the pitching foot (the foot on the same side as the pitching arm) (also called the pivot foot) takes a short step forward. This step is not allowed (by the rules) to be too long, as the pitching foot is supposed to be close to the rubber while the pitching motion is occurring. The pitching foot must also remain in contact with the ground as it slides forward- it is not supposed to be raised from the ground during the motion forward. When the pitching foot is planted in front of the rubber, the pitching arm starts to move forward (shoulder flexion) toward the front of the body. The pivot foot turns slightly to the side of the pitcher to allow the hips to rotate to an open position (Werner 1994).

Many windmill pitchers perform illegal movements during the windmill pitch, in that a long hop or leap is taken onto the back foot prior to planting the front foot for the pitch. Although a short step forward or slight leg drag is allowed, a long step or leap onto the back foot is actually illegal. A recent study of Olympic softball pitchers examined the whether a pitcher was actually airborne, dragged her back foot, or whether there was a secondary plant and drive (Byrd, Werner et al. 2003). Of the 21 pitchers examined, ten were airborne as the back foot left the rubber and four had a secondary plant and drive. Neither of these illegal actions resulted in an advantage in ball velocities when compared to pitchers using legal techniques. It was concluded that concern over possible increments in ball velocity due to these illegal movements is not warranted (Byrd, Werner et al. 2003). It should be noted that umpires seldom call pitchers for this dragging of the back foot, even though it occurs regularly in many pitchers.

The pitching arm moves forward at the same angular velocity as the other leg (the non pitching leg) begins to step forward. This motion forward of the front leg is important.
in increasing the forceful push-off from the pitching leg (Figure 4). The more forcefully the free leg and pitching arm move forward, the greater the ground reaction forces down and back on the push-off leg and the greater the velocity of the center of gravity that can be transferred to the ball. The acceleration of these limbs forward increases the forces on the back foot, increases the reaction force that drives the athlete forward.

As the front leg moves forward into the step, the trunk rotates sideways toward the pitching arm. For a right handed pitcher, the trunk rotates to the right so that it is facing third base at the top of the backswing, and the opposite shoulder is facing the batter. This sideways rotation of the trunk increases the range of motion of the pitching arm backwards and places the trunk muscles on a stretch prior to the forceful rotation back to face the batter (Figure 5).

**FIG. 5:** As the pitcher pushes off the pitching plate and steps forward, the pitcher rotates her trunk away from home plate allowing the pitcher to place the trunk muscles on the front of her body on a stretch. This position also helps the pitcher conceal the ball from the batter.
Force Producing Movements

As the short step onto the pivot foot is taken, the pitcher may lean forward to stretch the extensor muscles of the spine. The pitching arm then continues to move upward in front of the body using shoulder flexion, while the front leg starts to move downward toward the ground. The trunk and hips are rotated to a position facing sideways to the direction of the pitch as the arm circles upward and forward in front of the body. The back foot is also rotated so that the toe is now pointing sideways to the direction of the pitch, which ensures a full rotation of the hips and trunk sideways (Figure 6).

The pitching arm should remain extended at the elbow joint during the early part of the delivery, as the speed at the end of a longer lever is greater assuming that angular velocity can be maintained (Werner 1993). Since the fully extended arm takes longer to rotate around the shoulder axis, this allows more time for the action of the trunk to occur. An abbreviated arm swing with the elbow flexed that occurs faster may be associated with an abbreviated trunk rotation in which incomplete rotation occurs, which would likely decrease the velocity of the ball at release.

When the arm is drawn upward and backward during the delivery, the pitching arm should be kept close to the head and right ear, and should brush the right hip prior to delivery (Figure 7). These cues will help the pitcher to keep the arm on a straight path (Mogill 1984). Keeping the arm in this plane will result in a built in accuracy measurement for windmillers (Werner 1993). If the arm circle is performed so that the arm passes behind or too far from the head, the arm will likely be far from the hip at ball release. Pitchers who windmill the arm close to the body tend to have better control (Werner 1993). Although initially the movement at the shoulder consists primarily of shoulder extension, as the trunk rotates to a position sideways to the plate this movement becomes primarily abduction at the shoulder, which then becomes adduction as the arm moves back towards the trunk.
pitching arm is extended forward during the upswing of the pitching arm. As the pitching arm moves downward and trunk rotation is started, the non-pitching arm can contribute by driving diagonally downward and backward to assist in forceful trunk rotation (Werner 1994). From the position in front of the body at the start of the pitch, the non-throwing arm can be used to pull the non-throwing side backward as the throwing side moves forward (Figure 8). This produces forceful rotation of the shoulder girdle around the axis through the spine and horizontal adduction of the pitching shoulder.

The Stride

As the pitching arm is moving forward and the weight is being driven forward by the driving back leg, the pitcher will often perform a long hop on the pivot foot in the direction of the batter (Figure 9). This hop is legal as long as the back foot is not lifted from the ground. This hop can often cover several feet, and help to increase the velocity of the center of gravity toward the batter. This foot cannot be lifted from the ground during the glide, but it can only slide forward along the ground. Landing from the glide onto the pivot foot also helps to load the rear leg for the final push off toward the batter, so there should be some flexion of the back leg at the instant of landing following the glide. The pivot foot turns toward third base to allow the hips to rotate to an open or sideways position (Werner 1994). As the weight is driven forward from the back foot, the center of gravity follows a straight path toward the target with little vertical fluctuation until stride foot contact (Werner 1994). The front foot should be planted in alignment with home plate, and not too far to the left or right so that the momentum from the drive from the back foot is all directed towards the target. The orientation of the stride foot should be close to 45 degrees at landing to allow a full range of hip rotation backwards at the end of the backswing (Werner 1994).
The length of the stride onto the front foot is an important variable in pitching—the longer the stride the more skilled the pitcher. The stride length should be in the range of 80% to 100% of the pitcher’s standing height (Figure 11). A study of eight top US pitchers reported an average stride length of 73% of standing height with a range from 56 to 86 percent (Werner 1994). The longer stride will improve accuracy by flattening the arc at the bottom of the forward swing and increasing the time during which the pitch can be released accurately (Kirby 1969).

The body weight is then taken onto the front foot with the toe pointing at 45 degrees toward the batter and the knee is extended. The average knee angle at SFC (Stride Foot Contact) is 155 degrees (Werner, Murray et al. 1997). The stride knee is extended during the weight shift onto the leg and the front leg becomes an axis around which the body can rotate if hip and trunk rotation are used during the delivery. This leg usually remains extended throughout the release of the ball, although hyperextension of the stride knee is not ideal (Werner 1994). Some flexion of the front leg during delivery of the ball may reduce the forces on the front knee and help to absorb the forces of delivery. These forces include the forceful weight shift onto the front foot as well as the rapid rotation of the trunk around the fixed front hip.

The forceful landing on the stride foot in windmill pitching can lead to overuse injuries to the knee (Werner, Guido et al. 2005). Strength and conditioning regimes are recommended to strengthen the large muscles of the stride leg to withstand the high eccentric contraction forces at landing and release.

The front foot is planted (Stride Foot Contact- SFC) just as the arm begins to move downwards toward the ground. At the instant of stride foot contact the arm is at its furthest point behind the pitcher. This pattern helps to stretch the anterior trunk muscles of the pitcher to produce a more forceful trunk rotation toward the batter. The stride onto the front foot should not be too long; as if the stride is too long the pitcher will be unable to rotate the hips and trunk to the position facing the batter at release. At the instant that the arm is at its highest point (top of backswing –TOB) the front foot is about to contact the ground, so the arm and the free leg move downwards at the same time. The time from TOB to SFC has been reported to be .06 sec (Werner 1994). As the arm starts to move down toward the ground, the weight is shifted from the back leg to the front leg, and the trunk rotation from sideways to facing forward is initiated as the weight is being shifted forward. The weight shift forward is a critical aspect of windmill pitching, and is important to initiate trunk rotation and to move the weight onto the front foot and into the direction of the pitch to increase the force applied to the ball (Werner 1995).
**Trunk Rotation in Pitching**

In softball pitching the trunk does not rotate as a single unit, but the upper trunk (shoulder girdle or shoulders) and lower trunk (pelvic girdle or hips) rotate at different speeds and in sequence. This independent rotation of these two segments is important in maximizing the contribution of the trunk to ball speed in pitching. When examining the pitcher, the speed of each of these movements should be calculated separately. It has been reported that the maximum shoulder rotation speed was 750 deg/s with a range of 400 to 1200 deg/s, while the maximum hip rotation speed was 800 deg/s with a range of 300 deg/s to 1200 deg/s (Werner 1995).

As the pitching arm reaches a position parallel to the ground, the weight should be shifted fully onto the front foot and trunk rotation should be at least half completed (figure 12). Trunk rotation should lead the arm into the release position, so that the hips are almost facing the batter as the arm approaches the vertical position at release. In order to allow for full rotation of the trunk into the release position, the back foot must be unweighted and allowed to slide forward toward the front foot. The back foot is often airborne during this phase of the pitch. Trunk rotation is then rapidly decelerated prior to release of the ball, so the trunk is actually stationary through release. This rapid deceleration of the trunk may provide greater angular momentum to the arm and help to increase its angular velocity (Alexander and Haddow 1982).

A common error in pitching is to retain some weight on the back leg, which does not allow the hip of the pitching side to fully rotate forward (Alexander 1998). The back leg should be free of the ground, or at least sliding forward on the toe to produce optimal weight shift. If the hips do not rotate forward, as seen in many windmill pitchers (Figure 13), the pitcher will lose force that can be produced by the powerful muscles of the trunk (Alexander 1998). The hips need to rotate to a closed position toward home plate during the delivery phase, and
this position is facilitated by forceful back leg drive (Werner 1994). The full rotation of the trunk provides a significant transfer of momentum from the trunk to the pitching arm. In this position the back foot should be unweighted with the toe on the ground or completely off the ground (Figure 14).

The amount of hip rotation seen in skilled windmill pitchers is variable and a source of controversy among pitching coaches. Biomechanical principles suggest that a full range of trunk and hip rotation is needed prior to release of the ball in order to attain the maximum contribution from the trunk to ball velocity. Hip rotation in which the pelvic girdle faces home plate at release of the ball is a desirable technique. Hip rotation allows a full contribution from the lower body and trunk into the pitch. However, the majority of modern windmill pitchers do not rotate their hips forward to face the batter prior to release of the ball— they keep the hips facing sideways while the shoulders and pitching arm moves forward through release (Figure 15). This alters the shoulder movements so that the arm is undergoing shoulder adduction across the body at release instead of shoulder flexion. This technique forces the pitcher to throw across her body and lose potential contribution from the trunk and hip rotation (Werner 1994). It has also been suggested that the range of hip rotation is dependent on the type of pitch being thrown, with a drop ball requiring less hip and trunk rotation than a rise ball (Kinne 1987)

There are several possible reasons for this lack of...
rotation of the hips (pelvic rotation) to face the batter. It has been suggested that lack of hip rotation at release will decrease the forces on the pitching shoulder during release. This is likely due to the decreased stretch on the anterior shoulder capsule when the trunk is not rotated fully forward prior to the completion of the arm movements. The horizontal distraction forces acting across the shoulder are decreased when there is less trunk rotation. This position may also allow the pitcher to hide the ball more effectively until later in the delivery, making it more difficult for the batter to track the ball.

Arm Movements in Delivery

The shoulder joint is undergoing rapid shoulder flexion and adduction during the delivery, occurring at a velocity of over 2000\text{deg/s}. It has been reported that the peak windmilling arm speeds range from 1800 to 2400\text{deg/s}. This speed of motion at the shoulder joint is more than twice that reported for elbow flexion speed (Werner 1995). This rapid flexion produces high shoulder distraction (dislocating) forces that can lead to injuries to the shoulder. The windmilling speed of the throwing arm just prior to release of the ball should be decreased just before ball release. Pitchers with faster shoulder rotational speeds at release were found to have lower ball velocities at release (Werner, Murray et al. 1997). This deceleration of the shoulder rotation may allow some of the speed of the arm motion to be transferred to the ball (Alexander and Haddow 1982). The deceleration of the shoulder rotation prior to release requires a strong eccentric contraction of the shoulder extensors prior to ball release. As the shoulder is decelerating the elbow is flexing to increase the effectiveness of the shoulder medial rotation and lower arm pronation (Figure 17).

FIG. 17: The elbow is flexed just prior to release of the ball (top left frame) and will increases the effectiveness of shoulder medial rotation and pronation of the forearm.
bend the elbow more at release and into the follow through (Werner 1995). By flexing the elbow, less pull is created on the shoulder. Some of the energy from the shoulder is absorbed by the elbow bend, and the circular windmilling motion is stopped more quickly (Werner 1995). This may be due to the greater shoulder medial rotation that occurs when the elbow is flexed as compared to the extended elbow. Pitchers who maintain a straight arm into the follow through tend to continue the windmilling motion long after the ball has been released. These are the athletes that may encounter shoulder distraction forces equal or exceeding their body weights (Werner 1995).

Although the elbow is extended for much of the windmill motion, the elbow undergoes flexion just prior to release of the ball (Figure 17). The average elbow angle for elite pitchers was found to be 140-165 degrees at release (Werner 1994) (Figure 18). This elbow flexion helps to increase the moment arm for shoulder medial rotation and therefore increases ball velocity. The maximum reported flexion velocity for right handed pitchers was 966 d/s, with a range in the values between 645 to 1700 deg/s (Werner 1995).

The pitching arm should remain behind the trunk and in a supinated and laterally rotated position during the downswing behind the body. The velocity of the ball during this phase is from the shoulder flexion that is occurring on the downswing, as well as from the trunk rotation that is occurring. The most active muscle during this phase was found to be the pectoralis major muscle which was strongly active from the top of the backswing to ball release (Maffet, Jobe et al. 1997). At a point 2 frames prior to release (.066 s), the pitching arm begins the critical rotational movements to increase ball speed: lower arm pronation and upper arm medial rotation. The magnitude of the internal rotation torque relative to body weight appears to be greater for underhand throwing than for overhand throwing (Barrentine 1999). It has been concluded that internal rotation of the humerus produced by this internal rotation torque is a major contributor to ball velocity.

The ball is released in mid pronation and mid medial rotation as this is the point of peak angular velocity of these movements. Just prior to ball release a maximum internal

![FIG. 18](image1.png)

![FIG. 19](image2.png)

FIG. 18: All three pitchers from various developmental stages meet the criteria of elbow flexion.

FIG. 19: The pitching arm starts in a position of lateral shoulder rotation and forearm supination (as seen in frame 1) to a position of shoulder medial rotation and pronation of the forearm (frame 5).
rotation velocity of 4600 d/s is reached (Barrentine 1999). These movements are performed with the elbow slightly bent and the wrist abducted to maximize the length of the moment arm for these rotations from the axis to the ball. The axis for shoulder medial rotation passes through the long axis of the upper arm; and the axis for pronation occurs through the long axis of the lower arm. The flexed elbow and abducted wrist will help to increase the moment arms about these axes.

The pitcher also performs lateral trunk lean in the direction of the pitching arm during release- this movement increases the moment arm for both spinal rotation and rotation around the left hip. The axis for spinal rotation passes through the spine, so that slight abduction of the arm about the shoulder joint will increase this distance. The axis for rotation about the left hip passes through the left thigh, and leaning sideways away from this axis will increase the moment arm for rotation about this axis.

The pitcher also performs lateral trunk lean in the direction of the pitching arm during release- this movement increases the moment arm for both spinal rotation and rotation around the left hip. The axis for spinal rotation passes through the spine, so that slight abduction of the arm about the shoulder joint will increase this distance. The axis for rotation about the left hip passes through the left thigh, and leaning sideways away from this axis will increase the moment arm for rotation about this axis.

Deceleration of Proximal Segments

The angular velocities of the body segments should be decelerated in order, from proximal to distal so that each segment can make the maximum contribution to ball velocity. The trunk reaches maximum angular velocity first, then it will decelerate and some of the angular momentum generated by the trunk will be transferred to the pitching arm. The shoulder then reaches maximum flexion angular velocity, which is decelerated prior to release of the ball. Just prior to ball release, a maximum abduction torque and a maximum extension torque help to transfer momentum to the most distal segment and initiate deceleration of the upper arm (Barrentine 1999). During pitching, a peak shoulder extension torque is reached as elbow flexion is initiated, enabling momentum from the upper arm to be transferred to the lower arm. The upper arm segment slows as the lower arm segment speeds up prior to release of the ball.

Shoulder medial rotation and pronation then reach peak angular velocity and then decelerate, followed by wrist flexion and adduction. The timing of the segmental movements is that the more proximal segments attain peak acceleration before the more distal segments. After reaching peak velocity, the proximal segment is decelerated in order to transfer momentum to the distal segment (Alexander and Haddow 1982). Skilled pitching may be dependent on the ability of the performer to decelerate proximal segments.
in order. In this way some momentum is transferred from proximal to distal segments. One implication of this finding is that not only agonist (mover) muscles must be strengthened in skills of this type, but equally important is the ability of the antagonist muscles to perform this deceleration of a rapidly moving segment (Alexander and Haddow 1982).

**Critical Instant (Release of the Ball)**

At the instant of release (REL), the ball should be just anterior to the trunk, or just in front of the hip on the pitching side. The arm should be just past the vertical position. Just prior to release, the pitching arm should be in a position of supination and lateral rotation, in which the palm and the ball are facing sideways (toward third base for R handed). The elbow should be slightly flexed to produce a maximal moment arm for shoulder medial rotation. This cocked position of the pitching arm is important to allow for rotation in the opposite direction during release of the ball. During release, the lower arm should be pronating and the shoulder medially rotating to increase the velocity of the ball at release. At release, the arm should be in mid pronation (halfway between supination and pronation) and mid medial rotation, so that pronation and medial rotation are occurring at the fastest speed possible. From the side view, the back of the hand should be visible at release to show that rotation is occurring, as the hand has moved from a palm up position prior to release to a palm down position following release due to the rotations of the arm (Figure 21).

Many skilled windmill pitchers will contact their lateral thigh at the instant of release, which will stop or slow down the forward progression of the humerus. This contact with the thigh may help improve accuracy by producing a common point of release for every pitch and improve consistency of release. This action will also decrease the load on the rotator cuff muscles in deceleration of the high speed medial rotation and the triceps in deceleration of flexion of the humerus. Research has shown less rotator cuff activity in pitchers that contact their thigh with the humerus at release (Werner, Guido et al. 2005). This may lead to fewer rotator cuff injuries in pitchers that adopt this strategy.

The weight should be all on the front foot at release, the hips (pelvic girdle) should
be facing forward, and the trunk should be erect and not flexed forward excessively. Many

modern pitchers utilize a pitching style in which the hips are not rotated forward during delivery, but the hips remain facing sideways while the shoulders are rotated forward to face the batter. This may decrease the contribution from the rotation of the hips (pelvic rotation), but it may also produce greater force from the trunk rotation by providing a firm base on which the trunk rotators can pull during delivery (Figure 22). As well it may help the pitcher to hide the ball from the batter longer during delivery.

**Follow Through**

The purpose of the follow through is to decelerate the pitching arm over the greatest possible time and distance, to decrease the force per unit time and decrease the chance of injury. All the weight should now be shifted to the front leg, and the back foot should slide forward to a position just behind the front foot. There should be no weight remaining on the back leg during the follow through (Figure 23).

The pitching arm should follow through across the body and upwards, and finish in a position that reaches to at least shoulder height. The pitching arm will also continue to rotate in the direction of pronation and medial rotation, to decelerate pronation velocity over the greatest time and distance possible. The teres minor muscle was found to have the highest muscle activity during this phase, acting in protraction to prevent excessive retraction during release (Souza 2005). Many windmill pitchers experience extreme positions of rotation in the pitching arm during the follow through, in order to decelerate the arm rotations over the greatest time and distance possible. As the follow through ends, the weight is on the front foot, the back foot has moved up to a position parallel to the front foot, and the arm is at shoulder level and rotated to a palm down position. The pitcher should be balanced with the trunk erect, the glove up and the
eyes on the batter. The feet should assume a ready position with the feet at least shoulder width apart and the knees flexed in order to field a possible hit back to the pitcher (Figure 24).

**Temporal Analysis of Pitching**

A temporal analysis is a record of the timing patterns of the different phases of the windmill pitch. Several of the important timing patterns for the pitch have been reported (Werner 1994), and are included here. The average ball speed at release was 58 mph (93 kph) for eight elite American female pitchers, with a range from 53 (85) to 62 mph (100 kph) (Werner 1994). These values translate to an average release speed of 25.83 m/s, and a range of 23.7 m/s to 27.7 m/s.

The average time from the top of the backswing (TOB) until ball release was found to be .16 seconds. The range of times from TOB to REL for eight pitchers was found to be .13 to .19 seconds. Average times from TOB to stride foot contact (SFC), and SFC to REL were found to be .06 sec and .09 sec respectively. On average, the pitch is delivered from the top of the backswing to ball release in under .2 of a second. The time from TOB to SFC accounts for approximately 40% of the time, and the time from SFC to release accounts for 60% of the .16 sec (Werner 1994). From the time the stride foot touches down until the ball is released only .09 seconds have elapsed, which encompasses a large number of joint movements moving at a very high velocity.

**Measured Variables in Pitching**

One of the most consistent parameters in pitching is the elbow angle at ball release, which was found to be within 20 degrees for eight elite pitchers (Werner 1994). The average angle for the eight elite pitchers was 139 to 164 degrees. The speed of elbow flexion has also been found to be important in pitching skill, with the average speed reported to be 965 degrees per second, with a range from 644 to 1600 degrees per second. The speed of shoulder flexion just prior to release was found to average 1800 degrees per second, with a range of 1500 to 2300 degrees per second (Werner 1994).

The peak linear velocity of the center of gravity during the delivery is also a measure of the power and force of the drive from the mound. An average speed of 3.6 m/s to 3.4 m/s is common. It is likely that this greater peak CG velocity can assist in increasing the velocity of the ball at release, and is indicative of a more forceful push-off from the mound.

Stride angle can be calculated as the angle between a line drawn straight forward from the back ankle to the plate, and a line drawn from the back ankle to the front ankle. An angle of zero degrees would indicate that the stride foot landed directly in front of the pivot foot. An average angle for skilled pitchers is close to –3 degrees, in that the stride foot lands left of the pivot foot for a right handed pitcher (Werner 1994).

Stride foot orientation is the angle of the stride foot relative to home plate- an angle of zero degrees would indicate that the foot is pointed straight ahead. The average
stride foot orientation for eight elite pitchers is close to 30 degrees, so the stride foot was always turned toward a closed position at SFC (Werner 1994).

Knee angle at stride foot contact is a measure of the amount of flexion in the knee just following contact of the front foot. Values range from 160 degrees, suggesting a more extended knee at contact, to an average angle of 150 degrees so the knee was more flexed. This position is related to the individual style of each pitcher, and either is correct for a particular style.

Shoulder joint angular velocity averaged 1300 degrees per second for each of the 8 pitchers in this study, which is slightly less than the mean values reported for eight elite pitchers. The previous pitchers attained shoulder speeds of 2000 degrees per second (Werner 1995); although measuring techniques can affect the values produced in different studies.

The trunk rotation speed can be measured by two parameters: rotation of the shoulder girdle and rotation of the pelvis or hip rotation. Since the hips and trunk can rotate independently of each other, both the upper trunk rotation speed and the lower trunk rotation speed are calculated (Werner 1995). The average shoulder (referred to as trunk) rotation speed in this study was 600 degrees per second for subject HN, and 800 degrees per second for subject SN. These values compare favorably with those reported by (Werner 1995), with an average trunk rotation speed of 762 degrees per second with a range of 400 to 1200 degrees/second.

The hip rotation speed in this study was found to be 500 degrees per second for HN and 600 degrees per second for SN. These are slightly less than the average value for hip rotation reported by (Werner 1995) to be 796 degrees per second with a range from 300 to 1200 degrees per second.

Elbow flexion velocity is also reported in the literature (Werner 1995) for female windmill pitchers, with a mean value of 966 degrees per second and range between 645 and 1700 degrees/second. The pitchers in a recent study both attained elbow flexion values of close to 1100 degrees per second, suggesting that they may have more effective elbow motion in the pitch (Werner 1995). Another recent study reported the elbow angular velocity was 2520 deg/s at release of the ball (Kellen 2005). Note that elbow flexion likely occurs as part of lower arm pronation and shoulder medial rotation, which are difficult to measure from video film.
References

University of Manitoba

extremity ballistic skill: the windmill pitch." Canadian Journal of Applied Sport


stride leg drive of female Olympic softball windmill pitchers." Journal of the
International Council for Health, Physical Education, Recreation, Sport and Dance

Kellen, K. (2005) Biomechanics of the windmill softball pitch
www.cord.edu/homepages/kkellen/scipap.html.

56-57.

112.


1;42.

31.


World(December): 11.


FastPitch World(June): 14.


World(September): 24.

World(October): 22; 28.

World(February): 22.

