A THREE-DIMENSIONAL ANALYSIS OF THE WINDMILL STYLE OF SOFTBALL DELIVERY FOR FAST AND CHANGE-UP PITCHING

Sang Yeon Woo[1], and Eugene W. Brown[2]
[1]Department of Physical Education; Seoul National University; Seoul, Korea
[2]Institute for the Study of Youth Sports; Department of Physical Education and Exercise Science; Michigan State University; East Lansing, MI, USA

INTRODUCTION

With the current popularity of the sport and the importance of the pitcher to a team's success, a biomechanical examination of pitching techniques would be valuable to a large number of individuals interested in softball. Though research has been conducted on many aspects of softball, there is a paucity of research on the types of pitches. This may be associated with the complexity of analyzing the array of pitches used in softball.

The purpose of this study was to investigate the softball windmill pitching motion by analyzing the kinematics and kinetics of the throwing arm and ground reaction forces among three groups of highly skilled female pitchers. The following factors were examined: (1) temporal parameters, (2) ball velocity, (3) stride length, (4) angular velocity at the shoulder and elbow joints, (5) torque at the shoulder and elbow joints, and (6) ground reaction force. Understanding of the mechanics of fast and change-up pitches could provide information to coaches to assist their pitchers in developing command and control of ball velocity, accuracy, and technique, and to possibly prevent injuries.

METHODS

The volunteers were 18 highly skilled female pitchers who participated in softball leagues (six participated at the middle school level, six at the high school level, and six at the college level). All subjects selected were right-handed windmill pitchers.

Two video cameras were used to collect kinematic data. The field rate of the video cameras was 60 Hz. Shutters were set to 0.001s to minimize image blur. Four range poles were used to obtain the three dimensional coordinates of the control points required for the direct linear transformation (DLT) method used in the kinematic analysis.

An AMTI force platform measured three orthogonal components of the resultant ground reaction force. The force platform was secured to a metal mounting frame. The force platform and mounting frame were leveled prior to data collection. A wooden frame was constructed around the force platform and its surface was level with the surface of the force platform. This permitted the subjects to push off the force platform and to step onto the surface of the wood frame.

Force and videographic recordings were synchronized by matching a signal of a ball impacting the force platform immediately prior to each recorded pitch. For the video records, the subjects performed three trials of two different types of windmill pitches (fast and change-up). Data from one trial of each type of pitch for each subject was used for analysis. The, human body, modeled as 14 rigid body segments (head, trunk, arms, forearms, hands, thighs, shanks, and feet), was defined by 22 landmarks. One way ANOVA with repeated measures was applied to compare the three groups and also the two types of pitches.

RESULTS AND DISCUSSION

Four events determined three time intervals: (a) stride foot takeoff from force platform to ball release, (b) highest point of pitching arm to ball release, and (c) stride foot contact with the surface of the wood frame to ball release. The mean temporal elements for the three groups of subjects is presented in Table 1. The mean times for intervals (a), (b), and (c) for the fast pitches were significantly less than those for the change-up pitches ($p<.01$). Statistically there was no significant difference in intervals (a), (b), and (c) among the three groups. These results were also similar to other reports found in the literature (Werner, 1994a; Guenzler, 1979). This temporal data supports the idea that the windmill pitch is a highly dynamic activity. The windmill pitching motion takes a relatively short time period, requires extremely high speeds of upper extremity movement, and, therefore, a high degree of muscular contraction and coordination.

Table 1. Mean Temporal Elements (sec) of the Fast and Change-Up Pitches

Time Interval*	Middle School		High School		Collegiate	
	Fast	Change-Up	Fast	Change-Up	Fast	Change-Up
(a)	0.538	0.555	0.513	0.559	0.555	0.570
(b)	0.170	0.198	0.155	0.184	0.162	0.184
(c)	0.142	0.174	0.112	0.126	0.122	0.142

*Time intervals are defined in the text.

The mean velocities for the fast and change-up pitches are presented in Table 2. Among the three groups, there were no significant difference ($p<.01$) in ball velocity. When consolidating these results into differences in the average velocity between fast and change-up pitches, there was a significant difference between the two styles of pitching. Compared to previous studies of female collegiate pitchers, as reported by Kinne (1985) and Werner (1994a), the mean velocity of the fast pitch in the current study was similar. The differences in the ball velocity between the fast and change-up pitches for the middle school subjects were small compared with the other two groups. The data indicates that middle school subjects in this study seemed less skilled than high school and collegiate subjects in controlling the velocity of the change-up ball.

Table 2.
Mean Velocities (m/s) of the Fast and Change-Up Pitches

Type of Pitch	Middle School	High School	Collegiate
Fast	**21.22 ± 2.56**	**22.57 ± 2.39**	**23.39 ± 2.05**
Change-Up	**18.34 ± 1.11**	**17.03 ± 1.63**	**18.46 ± 1.54**

For each subject, stride length is reported as a percent of height. The mean normalized stride lengths for the fast and change-up pitches are presented in Table 3. There were no significant differences ($p<.01$) in the normalized stride length among the three groups. Also, the mean normalized stride lengths for the fast and change-up pitches within each group were not significantly different. It should be noted that increased stride length did not have a major effect on the ball velocity for both styles of pitches. It was observed that greater stride lengths were associated with subjects who tended to engage in a leaping motion (often referred to by softball participants as jumping). In fact, as in previous studies (Bridges, 1982; Werner, 1994b), a conclusion of this study, is that stride lengths of 80 to 90 percent of height could be considered appropriate for those who do not jump during the pitch, Also, the current study showed that the stride length for the two types of pitches among the three groups was similar.

Table 3.
Mean Stride Length as a Percent of Standing Height

Type of Pitch	Middle School	High School	Collegiate
Fast	83.3 ± 5.6	90.6 ± 11.9	95.3 ± 20.2
Change-Up	83.5 ± 8.4	89.2 ± 11.9	93.5 ± 20.7

Mean peak angular velocities for shoulder and elbow flexion are presented in Table 3. There were significant differences in mean peak shoulder flexion angular velocity among the three groups and between two styles of pitches ($p<.01$). Also, there were significant differences in mean peak elbow flexion angular velocity between two styles of pitches ($p<.01$), but there was no significant difference among the three groups. It has been established that flexion-extension angular velocity is an important contributor to ball velocity (Chung, 1988). The current study demonstrated that the peak angular velocity for shoulder joint flexion for the fast and change-up pitches was reached at approximately the middle of the execution phase and the peak angular velocity for elbow flexion was reached just prior to the release of the ball. This data implies that as the peak velocity for the arm was reached, the forearm began to rapidly increase in velocity. The other notable finding was that the peak angular velocity of the forearm occurred at almost the same instant as the release of the ball. This finding is in agreement with that of Alexander (1978), who also noted that a skilled performer will reach maximum angular velocity of the forearm segment at virtually the same instant as the ball release.

Table 4.
Mean Peak Angular Velocity (deg/s) for Joint Flexion

Pitch	Middle School					
houlder	1064.2	999.4	1369.7	1120.2	1152.6	1075.3
	± 154.7	± 142.6	± 104.2	f67.9	± 200.8	± 162.3
lbow	1492.5	1238.0	1430.6	1262.7	1479.5	1347.9
	± 171.5	± 144.6	± 136.3	± 130.5	± 124.1	± 189.4

The average flexion-extension torques for the shoulder and elbow for the execution phase of the pitches are presented in Table 5. There were no significant differences (p.<01) in average torque at the shoulder among the three groups, but a significant difference was found between two styles of pitches. Also, for average torque at the elbow joint, there were significant differences among the three groups and between the two styles of pitches.

An evaluation of the shoulder and elbow torque histories throughout the execution phase of the softball windmill pitching motion indicates the extent of muscle contraction. Large negative torque values at the shoulder joint were likely the result of the action of the extensor muscles of the shoulder, causing a reversal, or slowing down of the motion just prior to ball release. It is likely that the shoulder flexors are most active relatively early in the action, and that this activity is reduced prior to the point of the release of the ball. At this point, the shoulder extensors are likely very active as seen in a reversal of the resultant torque at the shoulder joint. They cause a reduction in the angular velocity of this segment. The large negative torques at the shoulder are accompanied by negative torques at the elbow. Even though both of these joints are flexing at the point of release, their extensors are active. This indicates that the dominant muscle group at the release of the ball was the shoulder extensors which were acting eccentrically as a brake to slow down the flexion of the arm at the shoulder joint. This is a very interesting finding because it had been common belief that the flexor muscles acted strongly up to the point of release.

Table 5.
Mean Flexion-Extension Torques (Nm)

Type of Pitch	Middle School		High School		Collegiate	
	Fast	Change-Up	Fast	Change-Up	Fast	Change-Up
Shoulder	-5.52	-2.54	-6.10	-3.32	-7.39	-5.45
	f 4.67	f4.23	f1.50	f3.20	f7.04	f4.86
Elbow	-0.97	-0.50	-2.07	-1.25	-5.33	-3.03
	f 1.14	f1.40	f1.38	f2.88	f2.93	f2.33

Of the three orthogonal ground reaction forces recorded, the vertical forces had the highest magnitudes and greatest change from maximum to minimum value. These are reported in Table 6. There were no significant differences in the peak vertical ground reaction force between two styles of pitch and also among the three groups. It was evident from the vertical ground reaction force records that there was relatively little difference in the mean maximum vertical values in most subjects between their fast pitch and change-up pitches. The similarity in the vertical ground reaction force of the pivot foot among the three groups seems to indicate that the difference in ball velocity may not have been significantly affected by the pivot foot in both styles of pitches.

Table 6.
Mean Maximum Vertical Ground Reaction Force (N)

Type of Pitch	Middle School	High School	Collegiate
Fast	736.72 ± 240	741.46 ± 144.17	814.12 ± 196.28
Change-Up	675.00 ± 182.64	727.04 ± 226.41	866.44 ± 189.48

CONCLUSIONS

Based upon the results'of this study, the following conclusions are recommended for teachers, coaches, and pitchers who are involved with fast and change-up windmill pitching in softball:

1. Stride length should not vary significantly for the fast and change-up pitches within a given pitcher. The recommended stride length range is 80 to 90 percent of a pitcher's height.

2. From the highest point of the backswing motion, the arm must be accelerated as forcefully and rapidly as possible. For this reason, a softball pitcher must have strong shoulder flexors and adductors.

3. Rapid deceleration, or slowing down of the arm prior to release of the ball, is another important action which occurs during the pitching motion. This is a critical action, requiring a softball pitcher to have very strong shoulder extensors.

4. Windmill softball pitchers need to work on specific strengthening exercises, especially of the shoulder, to execute these rotary movements effectively and also to prevent injuries.

5. The vertical ground reaction force of the pivot foot may not significantly contribute to ball velocity. The greater attention should be placed on the study of the ground reaction force of the stride foot.

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