A THREE DIMENSIONAL ANALYSIS OF THE WINDMILL SOFTBALL PITCH

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The act of performing the windmill softball pitch encompasses total body activity with activation of body parts through a link system. With the coordinated action of all body segments, ballistic energy is applied to the ball to result in the greatest produced velocity at the time of ball release. In attempt to improve performance, coaches and educators must understand the motions about the joints involved. Therefore it was the purpose of this study to determine the joint motions and movement patterns of the kinetic chain in the ballistic skill of performing the windmill pitch in attempt to improve athletic performance as well as athletic instruction.

KEY WORDS: throwing, mechanics, segmental contribution, technique, coordination, and sequentiality.

INTRODUCTION: The windmill softball pitch is a total body activity with sequential activation of body parts through a link system, which in a right-handed pitcher goes from the left foot to the right hand (Pappas, Zawacki, & Sullivan, 1985). With the coordinated action of all body segments, ballistic energy is applied to the ball to result in the greatest produced velocity at the time of ball release. When the velocity of the windmill softball pitch is a major contributor in the outcome of the game, the sequential activation of body segments in attempt to produce the highest velocity is of major interest. Many researchers have investigated the effects of limb segment movement during ballistic skills. Segmental analysis techniques in the literature have been explored extensively (Dillman, 1971; Miller & Shay, 1964; Youman, 1973; & Roberts et al. 1974). There have been inconsistencies in the literature on the timing of segmental motion during a ballistic skill. It has been documented that the joint with the highest angular velocity prior to release or impact is the major contributing factor for final limb velocity (Bunn, 1955; & Cooper, Adrian, & Glassow, 1982). To many coaches it appears that if the velocity of the proximal segments is decreased then there will be a decrease in the velocity of the distal segments, thus slowing the implement or object to be projected. In the past is was believed that during the kicking motion the thigh would slow or even stop before contact of the foot with the ball hence contributing nothing to the foot speed at ball contact (Roberts, Zernicke, Youman, & Huang, 1974).
With the lack of three-dimensional analysis on the windmill softball pitch, a coach or educator is limited on the available knowledge of proper mechanics in attempting to execute an effective delivery. Unfortunately, softball coaches have not recognized the sequential segmental movements present in softball pitching. In attempt to improve performance, coaches and educators must understand the motions about the joints involved. Therefore, it was the purpose of this study to determine the joint motions and movement patterns of the kinetic chain in the ballistic skill of performing the windmill pitch in attempt to improve athletic performance as well as athletic instruction.

METHODS: Three groups of participants were recruited for the study: novice, intermediate, and advanced. The novice pitcher was described as having zero to one year of experience pitching competitively. The intermediate pitcher was described as an individual who had completed two to three years of pitching competitively, while the advanced pitcher was classified as to having four or more years of experience or currently competing at the collegiate level. Seventeen female participants were selected for the study (six novice, six intermediate, and five advanced). Only right-handed participants were recruited, and all participants were injury free. Before any testing began, each participant read and signed a written informed consent agreement that was approved by Texas Woman's University Human Subjects Review Committee. Parental consent was obtained for all participants that were a minor prior to data collection.

After consent was given, anthropometric, height, and weight measurements were performed and recorded on each participant. Anthropometric data were based on the modified Hanavan method (Kwon, 1996). After all measurements were complete 19 one-centimeter reflective markers were placed on anatomical landmarks to aid in video digitizing. Each participant performed five successful, fastball windmill style deliveries using an official softball (12 in. circumference, 6 oz.). After completion of filming, each participant performed two baseline power tests, vertical jump and the Wingate anaerobic test. Analysis was performed three dimensionally through Kwon3D analysis system (Visol., Inc., Seoul, Korea). A six-camera set up was implemented with camera positioned at 60° apart. Field rate for each camera was set at 60 Hz with a shutter speed at 1/500s in attempt to decrease the blur.

The body model that was implemented for the study was based on point modeling of the 19 reflective markers. From the 19 reflective markers, joint centers (right, left hip, wrist, elbow, upper arm, right shoulder, and left shoulder) could be computed. The 19 points selected were chosen because the focus of the analysis was on the trunk and pitching arm segments: trunk, right upper arm, right forearm, and right hand. The hip joints were defined through the Tylkowski (1982) method through the identification of the right anterior superior iliac spine (ASIS), left ASIS, sacrum and inter ASIS distance. A wand positioned on the dorsal side of the wrist on the pitching arm, in line with the wrist joint center was used to determine the motion about the wrist. The wand was 12.7 cm (5 inches) in length with a reflective marker on the proximal and distal end of the wand. The wand's proximal marker was five centimeters from the dorsal surface of the wrist. To determine the joint center using a wand, one assumes that the joint center lies on the line defined by two markers fixed to the wand

Global and local reference frames determined the three-dimensional coordinates. The global right-handed orthogonal reference frame was fixed to the control object in the direction of motion Xg, Yg, and Zg. Yg was in the direction of the throw toward the target. Xg was perpendicular to Yg in a horizontal direction, while Zg was vertical. In order to establish a mathematically functional model, four Cartesian coordinate systems were established. The axis systems were segmentally based within each segment. The anatomical based axis systems defined motion in the trunk, shoulder, elbow, wrist and hand.

Statistical Analysis

Measures of central tendency were calculated for variables of interest: (a) sequential progression of the trunk, shoulder, elbow, and wrist; and (b) percent contributions of the trunk, upper arm, forearm, and hand and their contributions to ball velocity. Correlational statistics were calculated to assess the relationships between the angular motions of the trunk and upper arm; upper arm and forearm; and forearm and hand. An Analysis of Variance (ANOVA) with repeated measures at an alpha level of 0.05 was used to test the difference among groups between the linear velocities of the ball, wrist, elbow and shoulder at ball release. A multivariate analysis of variance (MANOVA) was used to examine the difference between the angular motion of the trunk, shoulder, elbow, and wrist at stride foot takeoff and their angular motion at stride foot plant, as well as the difference between angular motion of the trunk, shoulder, elbow, and wrist at stride foot plant and their angular motion at ball release.

RESULTS AND DISCUSSION: Demographic data revealed an average ball velocity for the advanced, intermediate, and novice groups of 21.6m/s, 20.7m/s, and 15.4m/s respectively. Vertical jump height for the advanced, intermediate, and novice groups averaged 16.4 inches, 15.2 inches, and 11.3 inches respectively. The Wingate power test quantified average power for the advanced, intermediate, and novice groups at 128.7W, 95.5W, and 58.4W respectively. To examine the sequential progression between the kinematic variables, the relationships between temporal events of the pairs of segments were assessed. The first time-derivatives (angular velocity) of the joint motions through the use of orientation angles of the joints were recorded at their maximums. The angular velocity was obtained based on segmental reference frames to determine the joint motion patterns: trunk (left/right rotation), shoulder (flexion/extension), elbow (flexion/extension), forearm (pronation/supination), and wrist (ulnar/radial deviation and flexion/extension).

There was evidence of sequentiality among the arm segments in the intermediate and advanced groups. The sequentiality was displayed by the fact that one segments reached its peak or maximum angular velocity then hundreds of a second later another segment reaches its maximum. The sequentiality was displayed from proximal to distal segments within the upper limb. It should be noted that in the intermediate and advanced groups, even though there was sequentiality within the arm segment, the trunk did not display the same trend. The trunk does not reach its maximum angular velocity until the point of ball release. The novice group failed to show a proximal to distal sequential trend.Sequentialness was displayed among the upper extremity segments for the advanced and intermediate groups. The novice group lacked displaying sequentialness between segments. Within the windmill pitch, sequentiality of upper extremity segments is not displayed until only hundreds of a second prior to ball release.Segmental contributions to ball velocity were examined between the trunk and upper arm; upper arm and forearm; and forearm and hand. The shared positive contribution was considered to be the interval in which the segments were both increasing in acceleration simultaneously divided by the total time of the movement to determine the total time both were contributing together.

The patterns of the contribution made by each of the limb segments were generally similar among the three groups of participants. The novice group tended to rely more on the upper arm and forearm than the other two groups. The results from the novice group are again indicative of the lack of segmental progression of the novice group versus the other groups. The novice group's percent contribution displayed the lacking of the participants ability to accelerate each segment in turn so that the succeeding segment lags behind, then acquire the speed to the segments moving it and then accelerate to reach even greater speeds.

Pearson correlations displayed a significant relationship with a strong negative correlation ($r = -.746$) between shoulder flexion and trunk left rotation, as well as a positive correlation between shoulder extension and elbow extension ($r = .814$) at stride foot off. At stride foot plant a significant positive correlation was expressed between forearm supination and wrist flexion ($r = .495$). When the shoulder displayed an increase in angular velocity, the trunk was displaying a decrease in angular velocity. Just as the shoulder showed an increase in angular velocity there is an increase in elbow and wrist's angular velocity.

In addition to the Pearson correlation, a regression analysis was also run to assess the predictability of the trunk's angular velocity predicting the upper arm; the upper arm predicting the forearm; and the forearm predicting the hand. No significance was found when assessing the trunk, upper arm, and forearm as predictors of the angular velocity of the hand [$F (2,12) = 0.215$, $p > .05$]. Regression beta weights provide evidence of the degree to which each variable contributes to the prediction. Despite that the prediction was not statistically significant, the beta weights as descriptive statistics suggested that the fist time-derivative (angular velocity) of the joint motions of the upper arm and forearm were primarily involved in the estimation of the angular joint motion velocity of the hand.

The ANOVA with repeated measures revealed a significant difference between groups for linear velocity [$F (2,14) = 4.504$, $p < 0.05$] of the ball, wrist, elbow, and shoulder at ball release. A Tukey HSD post-hoc test was used to determine which groups were significantly different. The post-hoc revealed that there was significance difference in linear velocities of the ball, wrist, elbow, and shoulder at ball release between the novice and advanced groups. However, there was no mean difference between the linear velocities of the intermediate group when compared to the novice and advanced groups.

The MANOVA revealed no significant difference in angular motion of the trunk; shoulder, elbow and wrist at the events of stride foot off and stride foot plant between the three different groups of participants. However, there was a reported significant difference between the three different events of stride foot off, stride foot plant, and ball release [$F (10,50) = 7.595$, $p < 0.01$]. Varimax rotated correlations between canonical and dependent variables suggest that the overall significance was due to changes in the elbow and trunk across each event. It should be noted that there was no significance in the changes in the shoulder and wrist across each event.

SUMMARY AND CONCLUSION: There was a definite sequence of proximal to distal segmental motions that are distinctive among the intermediate and advanced windmill softball pitchers. Even though the novice windmill softball pitchers did display characteristic sequentiality among segments it was not displayed in a proximal to distal sequence. This study represented the fact that the larger more proximal segments reach their peak angular velocities, followed by the next distal segment and eventually ending with the furthest distal segment reaching its maximal velocity. In this case it was the wrist/hand just prior to ball release. However, due to the natural phenomenon of the whipping motion of the windmill softball pitch, the sequentiality of the segments was not evident until hundreds of a second prior to ball release.

This study also revealed the sequentiality of proximal to distal segments in their contributions to ball velocity. Among all groups the hand was distinguished as allowing for the greatest contributory role in ball velocity. The more advanced windmill softball pitchers demonstrated the hand as having as much as 62% of total contribution to ball velocity. The hand contributions were followed by the forearm, upper arm, and trunk.

For coaches and educators, it should be noted that even though the shoulder and upper arm segments reach their peak velocities at stride foot plant, their role in the prediction of ball velocity is still very important. Just as Putnam (1993) has stated, even thought the more proximal segments of the shoulder and upper arm do not make large kinematic contributions to the distal end speed at the instant of release, their motion histories are such that they make it possible for the distal end to achieve a high speed. This study found that even with the most novice to the most advanced windmill softball pitchers, there is a distinct role that each segment plays in the prediction of ball velocity. Therefore, coaches and educators should note that if the hand displays the greatest percent of contribution, then one should focus on the velocity production about the forearm, wrist, and hand motion versus concentrating on trying to increase the velocity about the shoulder. This concept of trying to achieve the greatest angular velocity about the shoulder joint has become a downfall by many coaches and educators in the past. Coaches and educators should focus on the entire arm segment in attempt to reach its greatest velocity while performing the 360° arc of the windmill pitch. Then the focus should shift towards accelerating the elbow, wrist, and hand just prior to ball release.

Within the scope and limitation of this study, several conclusions can be made. The more advanced and intermediate windmill softball pitcher displays a proximal to distal sequencing of arm segments in the execution of the fastball, windmill softball pitch; which essentially leads to greater ball velocity than the novice windmill softball pitcher. The advanced windmill softball pitcher most effectively decelerates the angular velocity of the proximal segments in essence to accelerate the most distal segment, which in turn produces the greatest ball velocity. As a coach or educator, focus should be spent on the proper sequencing of segments in attempt to achieve the greatest velocity at the most distal segment for the production of the greatest ball velocity.

REFERENCES:

Bunn, J.W. (1955). Scientific principles of coaching. Englewood Cliffs, NJ: Doubleday & Company.

Clauser, C.E., McConville, J.T., & Young, J.W. (1969). Weight, volume and center of mass of segments of the human body (AMRL-TR-69-70). Aerospace Medial Research Laboratory, Wright-Patterson Air Force Base, Ohio.

Cooper, J.M., Adrian, M., & Glassow, R.B. (1982). Kinesiology (5th ed.). St. Louis: The C.V. Mosby Company.

Dillman, C.J. 'A kinetic analysis of the recovery leg during sprint running', in Biomechanics, J.M. Cooper, ed., Chicago: The Athletic Institute, 1971.

Kwon, Y.-H. (1996). Effects of the method of body segment parameter estimation on airborne angular momentum. Journal of Applied Biomechanics, 12, 413-430.

Miller, R.G. & Shay, C.T. (1964). Relationship of reaction time to the speed of a softball. Research Quarterly, 35, 433-437.

Pappas, A.M., Zawacki, R.M., Sullivan, T.J. (1985). Biomechanics of baseball pitching. A preliminary report. The American Journal of Sports Medicine, 13, (4), 216-222.