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ORIGINAL RESEARCH

# PITCHING MECHANICS IN FEMALE YOUTH FASTPITCH SOFTBALL

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## ABSTRACT

***Background:*** Fastpitch softball is a popular sport for young females. However, data are limited describing youth pitching mechanics. Normative data describing pitching mechanics in the two youngest player pitch leagues are critical to gaining an improved understanding of proper mechanics in an attempt to establish injury prevention programs.

***Purpose:*** The purpose of this study was to examine pitching mechanics in Little League softball pitchers and examine the relationship of these mechanics and participant anthropometrics to ball velocity.

***Study Design:*** Cross-sectional.

***Methods:*** Twenty-three youth softball pitchers (11.4 ± 1.5 years; 154.6 ± 10.5 cm; 51.0 ± 8.0 kg) participated. An electromagnetic tracking system was used to collect kinematic data for three fastball trials for strikes over a regulation distance to a catcher. The pitching motion was divided into three events: top of back swing, stride foot contact, and ball release.

***Results:*** Youth who were older ($r = 0.745$, $p < 0.001$) and taller ($r = 0.591$, $p = 0.003$) achieved greater ball velocity. Trunk kinematics revealed that greater trunk flexion throughout the three throwing events of top of back swing ($r = 0.429$, $p = 0.041$), stride foot contact ($r = 0.421$, $p = 0.046$), and ball release ($r = 0.475$, $p = 0.022$) yielded greater ball velocity. Additionally, greater trunk rotation to the throwing arm side ($r = 0.450$, $p = 0.031$) at top of back swing and greater trunk lateral flexion to the glove side at ball release ($r = 0.471$, $p = 0.023$) resulted in greater ball velocity.

***Conclusion:*** The significant relationships found between pitching mechanics and ball velocity only occurred at the trunk, which may highlight the importance of utilizing the trunk to propel the upper extremity in dynamic movements.

***Level of Evidence:*** Diagnosis, Level 4.

***Key Terms:*** Little League; Mechanics; Shoulder; Pitching

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## INTRODUCTION

The windmill softball pitch is a dynamic movement in which the athlete rapidly moves their arm in a circular motion to produce an underhand pitch. A common misconception regarding the softball pitch is that it produces less stress on the shoulder than the overhead baseball pitch, however, the literature does not support this notion.[1-3] Recent studies have revealed that the windmill softball pitch generates similar forces about the shoulder as those seen in overhand pitching.[2,3] Studies examining softball pitching mechanics have focused primarily on kinetics, or forces, about the shoulder and elbow,[1-3] ground reaction forces,[3-5] and segmental speeds.[1-3,5] However, these studies have included wide age ranges and skill levels of participants, and no study, has described the kinematics of the youngest level of competitive softball pitchers.

Approximately 260,000 athletes participate in Little League softball's four age-based divisions.[6] Despite the high number of young athletes participating in the sport, there are limited biomechanical data describing the windmill pitch in the younger divisions of Little League softball. With the high participation in the sport, it is paramount that young athletes are instructed on proper pitching mechanics.[6] The current literature contains more data on proper pitching mechanics in baseball compared to softball. Yet, forces about the shoulder and elbow are similar between the baseball and softball pitches despite the fundamental differences in the motions.[1-3] The National High School Sports-Related Injury Surveillance Study found that from 2006-2012 injury rates of softball athletes are comparable or exceed those in baseball athletes.[7] Studies describing softball pitching kinematics at the younger divisions are warranted in an attempt to educate coaches and sports medicine personnel on proper pitching mechanics in an attempt to reduce injury susceptibility. The purpose of this study was to (1) examine pitching mechanics in Little League softball pitchers and (2) examine the relationship of these mechanics and participant anthropometrics to ball velocity.

## METHODS

The independent variables in this study were the kinematic parameters (trunk flexion, trunk lateral flexion, trunk rotation, pelvis anterior/posterior tilt, pelvis lateral flexion, pelvis rotation, shoulder horizontal abduction, shoulder elevation, elbow flexion, stride leg knee flexion, and stride length) and participant anthropometrics (age, height, and weight) and the dependent variable was ball velocity.

Twenty-three female softball pitchers (11.4 ± 1.5 years; 154.6 ± 10.5 cm; 51.0 ± 8.0 kg) were enrolled and reported to the Sports Medicine and Movement Laboratory for data collection. Participants were recruited from local youth fast-pitch softball teams via email contact with their respective coaches. Selection criteria included being currently active on the playing roster for the position of pitcher to ensure that all participants were competitively active at the pitching position. Potential participants with a history of upper or lower extremity injury within the prior six months were excluded. Participants played Little League softball and had 2.3 ± 1.3 years of experience. The Institutional Review Board of Auburn University approved all testing protocols. Prior to data collection, all testing procedures were explained to each participant and their parent(s)/legal guardian(s) and informed consent and participant assent were obtained.

### Procedures

All kinematic data were collected with The MotionMonitor™ (Innovative Sports Training, Chicago, IL) synchronized with an electromagnetic tracking system (Track Star, Ascension Technologies Inc., Burlington, VT). Eleven electromagnetic sensors were attached to the following locations: (1) the posterior/medial aspect of the torso at T1, (2) posterior/medial aspect of the pelvis at S1, (3-4) bilateral distal/posterior aspect of the upper arm at the deltoid tuberosity, (5) the flat, broad portion of the acromion of the throwing scapula, (6-7) bilateral distal/posterior aspect of the forearm, (8-9) bilateral distal/lateral aspect of the lower leg centered between the head of the fibula and the lateral malleolus, and (10-11) bilateral distal/lateral aspect of the upper leg (femur).[5,8-14] Medial and lateral aspects of each joint were identified and digitized. Joint centers were calculated by the midpoint of the two points digitized. A link segment model was then developed through digitization of bony landmarks used to estimate the joint centers for the ankle, knee, hip, shoulder, thoracic vertebrae 12 (T12) to lumbar vertebrae 1 (L1), and cervical vertebrae 7 (C7) to thoracic vertebrae 1 (T1). The spinal column was defined as the digitized space between the associated spinous processes, whereas the ankle and knee were defined as the midpoints of the digitized medial and lateral malleoli, and the medial and lateral femoral condyles, respectively.[5,8-12,15]

The shoulder and hip joint centers were estimated using the rotation method as it has been shown to provide accurate positional data.[16] The shoulder joint center was calculated from the rotation between the humerus relative to the scapula, and the hip joint center was calculated from the rotation of the femur relative to the pelvis. The point on the humerus or femur that moved the least according to a least-squares algorithm allowed for the calculation of the joint centers. The variation in the measurement of the joint center had to have a root mean square error of less than 0.001 m in order to be accepted. All kinematic data were sampled at a frequency of 100 Hz. Raw data regarding sensor orientation and position were transformed to locally-based coordinate systems for each respective body segment. Pelvis, torso, and upper extremity kinematics were defined by the standards and conventions of The International Shoulder Group and International Society of Biomechanics.[15,17] Stride length was calculated as the distance between bilateral lateral malleoli at the event of foot contact. To enable comparisons between participants, stride length data were normalized to body height.[2]

Once all sensors were secured, participants were given an unlimited time to perform their own specified pre-competition warm-up (average warm-up time was 8 minutes). Participants were instructed to pitch three fastballs at maximum effort for strikes over a regulation distance to a catcher. As per the standards of the Little League (Major Division), the participants 9-11 years of age threw a distance of 40 ft. (12.19m), while those 12-13 years of age pitched 43ft (13.11m) according to the Junior Division standards.[6] Data for each kinematic variable were averaged for the three fastball pitches during data analysis in effort to limit potential variability between pitches. For the purpose of this study, the arm contralateral to the throwing arm was defined as the glove side. The stride leg was defined as the leg contralateral to the throwing arm. The pitching motion was divided into the events of top of backswing, stride foot contact, and ball release and all variables were analyzed at these events[2,3] (Figure 1).

### Statistical Analysis

Data were analyzed using IBM SPSS Statistics 23 (IBM corp., Armonk, NY). Eleven kinematic parameters (trunk flexion, trunk lateral flexion, trunk rotation, pelvis anterior/posterior tilt, pelvis lateral flexion, pelvis rotation, shoulder horizontal abduction, shoulder elevation, elbow flexion, stride leg knee flexion, and stride length) were analyzed. Means and standard deviations were calculated for each variable. Pearson product-moment correlations were run to assess the relationships between age, height, weight, and pitching kinematics to ball velocity. The alpha level was set *a priori* at $p \leq 0.05$.

## RESULTS

Data describing fastball pitching mechanics are presented in Tables 1 and 2.

The results of the correlations between variables and ball velocity are presented in Table 3. Average ball velocity for the examined sample was 40.5 ± 6.5 mph (18.1 ± 2.9 m/s). When examining participant demographics of age and height, it was found that youth who were older ($r = 0.745$, $p < 0.001$) and taller ($r = 0.591$, $p = 0.003$) achieved greater ball velocity. Examining the relationship between pitching kinematic parameters and ball velocity, results revealed that greater trunk flexion throughout the three throwing events of top of back swing ($r = 0.429$, $p = 0.041$), stride foot contact ($r = 0.421$, $p = 0.046$), and ball release ($r = 0.475$, $p = 0.022$) yielded greater ball velocity. Additionally, greater trunk rotation to the throwing arm side ($r = 0.450$, $p = 0.031$) at top of back swing and greater trunk lateral flexion to the glove side at ball release ($r = 0.471$, $p = 0.023$) resulted in greater ball velocity.

## DISCUSSION

The purpose of this study was to (1) examine pitching mechanics of youth softball pitchers at the Little League level and (2) examine the relationship of

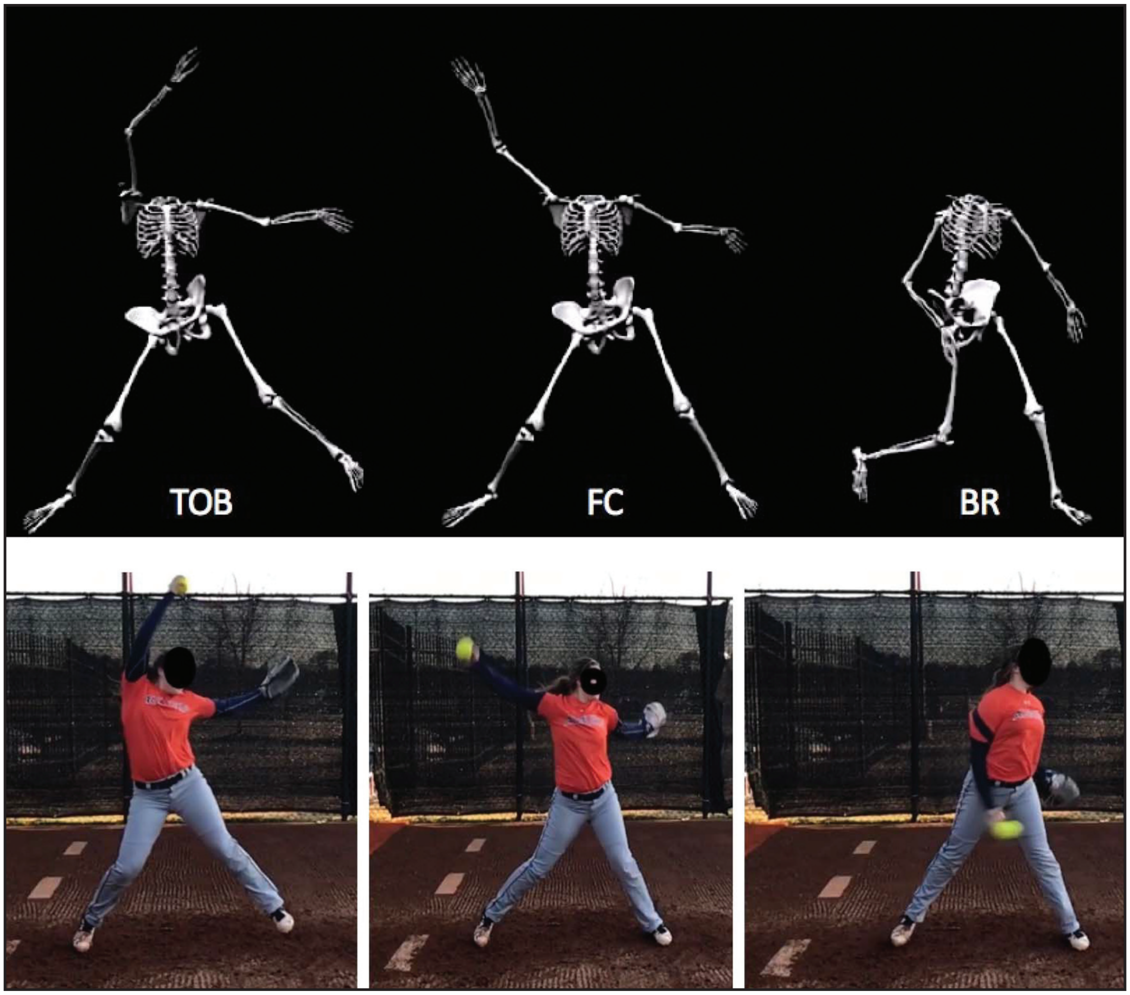


**Figure 1.** *Pitching events. TOB = top of back swing; FC = foot contact; BR = ball release.*

these pitching mechanics and participant anthropometrics on ball velocity. Regarding pitch mechanics, results from this study are consistent with previous research by Werner et al., which also examined youth softball athletes.[3] At the lower extremity, stride knee flexion was approximately 30° from full extension at stride foot contact, and both studies observed 43° of pelvic rotation towards the throwing arm side, resulting in a near closed position at ball release. At the upper extremity, participants in the current study displayed greater shoulder elevation at stride foot contact with approximately 123° versus 109° in the Werner study and again at ball release with 15° versus 3°. Participants in this study had greater elbow flexion of 31° from full extension compared to 20° at ball release. Overall, mean ball velocity of these participants was slower at 18 m/s versus 25 m/s. These subtle discrepancies could be an effect of age, as participants in this study ranged from 9 to 12 years of age, while participants in Werner et al. ranged from 11 to 19 years.

In analysis of kinematic relationships to ball velocity, youth softball pitchers who were older and taller had greater ball velocity. The relationship between age and ball velocity is not surprising, as strength is generally gained as one matures. It is interesting to note that height was significantly correlated with ball velocity, while stride length was not significant. Though height is a controlling factor of stride length, it was found that stride length did not play a role in ball velocity. The relationship of height and ball velocity may be the result of maturation, through bone and muscle growth and development, versus stride length. It can be postulated that pitchers who were taller could have longer segments and the potential to generate greater torque during the windmill pitching motion. Furthermore, pitchers in this study displayed

**Table 1.** *Lower extremity pitching mechanics during the fastball by event of pitching motion.*

| | TOB<br>Mean, SD | FC<br>Mean, SD | BR<br>Mean, SD |
|---|---|---|---|
| **Pelvic Anterior (°)** | 12 ± 11 | 8 ± 11 | 2 ± 10 |
| **Pelvic Lateral Flexion (°)** | 8 ± 9 | 10 ± 11 | 16 ± 7 |
| **Pelvic Rotation (°)** | -76 ± 12 | -75 ± 11 | -44 ± 12 |
| **Trunk Extension/Flexion (°)** | 1 ± 18 | 68 ± 17 | -1 ± 12 |
| **Trunk Lateral Flexion (°)** | -3 ± 15 | 5 ± 13 | 12 ± 9 |
| **Trunk Rotation (°)** | -62 ± 32 | -69 ± 33 | -30 ± 28 |
| **Stride Knee Flexion (°)** | - | 29 ± 10 | 27 ± 11 |
| **Stride Length (%height)** | - | 61 ± 9 | - |

* indicates statistically significant difference $p \leq 0.05$
TOB = Top of Back Swing; FC = Foot Contact; BR = Ball Release
Pelvic Rotation: (-) denotes towards throwing arm side; Trunk Extension = reported as (-); Trunk Flexion = reported as (+); Trunk Lateral Flexion: (+) denotes towards throwing arm side; Trunk Rotation: (+) denotes towards the glove side, (-) denotes towards throwing arm side.

**Table 2.** *Upper extremity pitching mechanics during the fastball by event of pitching motion.*

| | TOB<br>Mean, SD | FC<br>Mean, SD | BR<br>Mean, SD |
|---|---|---|---|
| **Shoulder Horizontal Abduction (°)** | 72 ± 34 | 18 ± 44 | -3 ± 44 |
| **Shoulder Elevation (°)** | 127 ± 29 | 123 ± 18 | 15 ± 11 |
| **Elbow Flexion (°)** | 35 ± 22 | 24 ± 18 | 31 ± 15 |
| **Ball Velocity (mph)** | - | - | 41 ± 7 |

* indicates statistically significant difference $p \leq 0.05$
TOB = Top of Back Swing; FC = Foot Contact; BR = Ball Release
Shoulder horizontal abduction: (-) denotes in front of torso, (+) denotes behind torso; Elbow flexion: angle is reported in reference to the extended line of the humerus

a stride length of approximately 61% of body height comparable to that of the Werner study at 62%. Longer stride lengths of softball pitchers have been found to increase ball velocity due to the increased propulsive force that leads to a longer stride.[4] However, there must be a point of diminishing return with regard to increased stride length, because the body must be in an optimal position to create resistance against which the body can rotate through to ball release.[4] Striding too long will cause the pitcher's center of mass to be located closer to the back foot rather than centered within the base of support, thereby decreasing the ability to quickly create enough force for resistance immediately following stride foot contact.

The effects of trunk flexion, lateral flexion and rotation on ball velocity demonstrate that at top of back swing, pitchers with more trunk flexion and trunk rotation towards the pitching arm were able to produce greater ball velocity (Figure 2). This position would have the pitcher with their glove side shoulder pointing to home plate. Then at ball release, those who had greater ball velocity had more trunk forward flexion and their trunk was more laterally flexed to the glove side. The influence of the trunk mechanics on ball velocity reiterates the importance of the lumbopelvic-hip complex as the base for all distal mobility.[18] Having a stable lumbopelvic-hip complex allows for optimum force production and

**Table 3.** *Pearson correlation statistics for ball velocity.*

| | TOB<br>*r, Sig.* | FC<br>*r, Sig.* | BR<br>*r, Sig.* |
|---|---|---|---|
| **Trunk Flexion (°)** | **0.429, 0.041*** | **0.421, 0.046*** | **0.475, 0.022*** |
| **Trunk Lateral Flexion (°)** | 0.045, 0.837 | -0.066, 0.763 | **0.471, 0.023*** |
| **Trunk Rotation (°)** | **0.450, 0.031*** | 0.287, 0.184 | 0.201, 0.357 |
| **Pelvis Anterior Tilt (°)** | 0.159, 0.470 | 0.138, 0.529 | 0.310, 0.149 |
| **Pelvis Lateral Flexion (°)** | -0.246, 0.257 | -0.213, 0.329 | 0.207, 0.343 |
| **Pelvis Rotation (°)** | -0.196, .370 | -0.139, 0.526 | 0.129, 0.557 |
| **Shoulder Horizontal Abduction (°)** | 0.020, 0.929 | -0.053, 0.809 | 0.313, 0.145 |
| **Shoulder Elevation (°)** | 0.311, 0.149 | 0.330, 0.124 | 0.353, 0.099 |
| **Elbow Flexion (°)** | -0.300, 0.164 | -.357, .095 | -0.064, 0.773 |
| **Stride Knee Flexion (°)** | -0.110, 0.616 | -.237, 0.277 | -0.336, 0.117 |
| **Stride Length (% height)** | - | 0.195, 0.373 | - |
| | | | |
| **Age** | **0.745, 0.000*** | | |
| **Height** | **0.591, 0.003*** | | |
| **Weight** | 0.240, 0.271 | | |

****bolded text*** indicates statistically significant correlation $p \leq 0.05$
TOB = Top of Back Swing; FC = Foot Contact; BR = Ball Release
Pelvic Rotation: (-) denotes towards throwing arm side; Trunk Extension = reported as (-); Trunk Flexion = reported as (+); Trunk Lateral Flexion: (+)denotes towards throwing arm side; Trunk Rotation: (+) denotes towards the glove side, (-) denotes towards throwing arm side; Shoulder horizontal abduction: (-) denotes in front of torso, (+) denotes behind torso; Elbow flexion: angle in reference to the extended line of the humerus.

transfer to the most distal segment of the wrist and hand.[18] Thus, the trunk kinematics presented by the youth in the current study contributed to the ability to achieve greater ball velocity.

Smith et al.[19] recently reported that 38% of the examined softball pitchers (aged 9-18) suffered an injury related to pitching over the course of a competitive season, and of these injuries, 61% involved the shoulder. Previous research in baseball pitching has reported that the greater the ball velocity of a pitch, the greater the forces that occur about the shoulder and elbow. Large forces about the shoulder and elbow may contribute to injury.[20] While the current study did not examine forces, ball velocity may be an important indicator of forces at the upper extremity and understanding the variables that are related to ball velocity, including pathomechanics at the shoulder and elbow, are critical. Ball velocity data are easier to obtain than the sophisticated throwing mechanics data that are currently presented and may be a tool clinicians and coaches can use as a proxy to infer mechanics and forces that youth pitchers incur.

Previously, Kibler has reported that during dynamic overhead movements 63-74% of kinetic energy is generated by the hip/trunk segments.[21] The significant relationships, found in the current study, between pitching mechanics and ball velocity only occurred at the trunk, which may highlight the importance of utilizing the lower body and trunk to propel the upper extremity in dynamic movements.[18,22] If the hip/trunk have altered movement patterns, then the kinetic energy transferred to the upper extremity may be decreased. In order to compensate for potential decreased energy transfer,

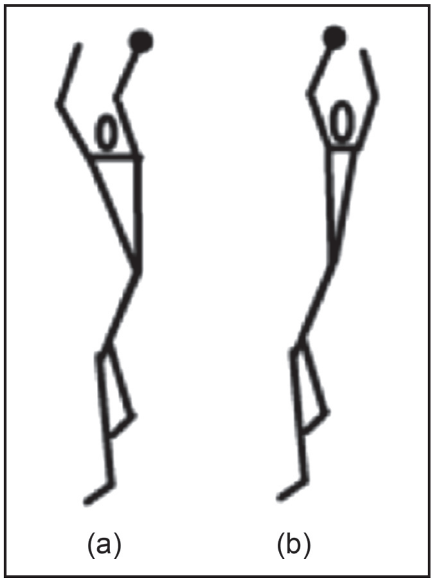


**Figure 2.** *Trunk positioning for increased ball velocity. (a) Pitcher with greater trunk flexion and rotation towards the throwing arm side, with back slightly towards the target. (b) Pitcher with less trunk flexion and rotation.*

the upper extremity must generate greater kinetic energy.[23]

While this study provides valuable insight into youth softball pitching mechanics, it is important to note that limitations exist. The participants were from a relatively small geographic area. These results may not apply to all youth softball pitchers. A convenience sample of participants were recruited and the sample size was moderate. Additionally, these participants were in Little League softball's youngest divisional levels that allow youth to pitch. These pitchers generally have the least pitching experience and are still learning how to pitch effectively. Another limitation to this study is the cross-sectional design that only examined results from a single laboratory session's pitching performance. A protocol that more closely represents the demands of competitive youth softball may more accurately reflect mechanics during pitching. Future research should aim to characterize the risk of pitching mechanics on upper extremity injury. Other potential factors contributing to injury risk should also be considered, such as muscular performance impairments and range of motion deficits that can enable a comprehensive characterization of risk of injury in youth pitchers.

## CONCLUSION

Understanding the pitching kinematics of individuals in the youngest division of Little League Softball can be of benefit to not only sports medicine personnel, but also training/conditioning specialist as well as pitching coaches. These data suggest that increased trunk rotation to the throwing arm side at top of back swing, increased trunk flexion throughout the pitch, and increased trunk lateral flexion to the glove side at ball release may improve pitching performance via increasing ball velocity. Using this evidence, sports medicine personnel and coaches can suggest potential improvements in pitching mechanics of the youth population as well as may inform the development of strength and conditioning programs focused on trunk and pelvic stability for greater postural control of the lumbopelvic-hip complex (LPHC). The LPHC is the connecting link of the lower extremity to the upper extremity for efficient transfer of energy. Focus on LPHC stability as well as postural control could ultimately assist in not only pitching performance but also injury prevention in youth softball pitchers.

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