THE RELATIONSHIP BETWEEN STRIDE MECHANICS AND SHOULDER DISTRACTION FORCE IN COLLEGIATE SOFTBALL PITCHERS

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The purpose of this study was to determine the relationship between stride mechanics and shoulder distraction force in softball pitchers. Sixty-three collegiate softball pitchers participated and threw three maximal effort fastballs for a strike. Kinematic data were collected using an electromagnetic tracking system with a sampling frequency of 100 Hz. Regression analysis revealed a significant positive relationship between stride length and shoulder distraction force [R^2 = .11; F (1, 61) = 7.345, p = .009], where stride length accounted for 11% of the variation in shoulder distraction force. Specifically, shoulder distraction force increased by .94 N/kg for every 10% increase in stride length normalized as a percentage of body height. Coaches and players should be aware of the negative effect of greater stride length on susceptibility to upper extremity injury.

KEYWORDS: Stride length, Stride position, Upper extremity kinetics, Windmill pitch

INTRODUCTION: The windmill softball pitch is a dynamic movement with similar upper extremity forces as the baseball pitch (Barrentine et al., 1998). It is known that a longer stride influences the timing of the baseball pitch and indirectly leads to greater elbow kinetics (Matsuo et al., 2001; Hirashima et al., 2002). Additionally, baseball pitchers with longer strides typically have greater ball velocities which is also associated with greater throwing arm kinetics (Manzie et al., 2021). Softball pitching research indicates a longer stride length is associated with higher pitch volume (Downs et al., 2020), increased ball velocity (Downs Talmage et al., 2021; Oliver et al., 2018; Werner et al., 2006), and greater vertical ground reaction forces (Oliver & Plummer 2011). Although the relationship between stride length and upper extremity stress is unknown, an examination of collegiate softball pitchers reported those with upper extremity pain displayed greater stride lengths compared to those without pain (Oliver et al., 2018, 2019). Further, stride position (open or closed) is a variable associated with upper extremity injury risk in baseball pitching (Fleisig et al., 1995; Slowik et al., 2021; Manzi et al., 2022). Specifically, a more open stride width is associated with greater shoulder kinetics and decreased stride length (Fleisig et al., 1995). Manzi et al., (2022) also determined there is an association between stride position with decreased pelvis rotation at foot contact, which is additionally linked to increased shoulder kinetics. Although there have been several investigations into the mechanics of the windmill softball pitch, there are a paucity of data regarding the relationship between stride mechanics and shoulder kinetics. Therefore, the purpose of this study was to examine the influence of stride mechanics (stride length and stride foot position) on shoulder distraction force in collegiate softball pitchers. Based on prior research, it was hypothesized shoulder distraction force would increase with a longer stride length and a more open stride position.

METHODS: Sixty-three Division I National Collegiate Athletic Association softball pitchers [right-handed (n = 51); age: 20.1 ± 1.3 yrs, height: 173.3 ± 7.4 cm, weight: 79.7 ± 11.7 kg], participated. All testing procedures were approved by the University’s Institutional Review Board. Inclusion criteria required participants to be actively competing on a collegiate team roster as a pitcher as well as injury and surgery free for the past six months. Kinematic data were collected at 100 Hz with an electromagnetic tracking system (trackSTAR Ascension Technologies Inc.’ Burlington, VT, USA) synched with The MotionMonitor XGen software (Innovative Sports Training, Chicago, IL) (Downs Talmage et al., 2020, 2021; Oliver et al., 2018, 2019). Participants arrived at the indoor pitching laboratory donning tee shirt, shorts, and turf shoes. Fourteen electromagnetic sensors were attached to the participants using previously established standards (Oliver et al., 2018; Wasserberger et al., 2021). Position and orientation of body segments were consistent with International Society of Biomechanics

recommendations (Wu et al., 2005). The laboratory reference frame was defined as the positive Y-axis in the vertical direction, anterior/posterior of the Y in the direction of movement was the positive X-axis, and orthogonal to the X-Y axes and to the right was the positive Z-axis. The kinematic parameters analyzed at foot contact included stride length normalized to a percentage of body height and stride foot position. Stride length was defined as the distance in the X – position of the stride foot ankle relative to the drive foot ankle at the initiation of the pitch. Stride foot position was defined as the difference in the Z-position of the stride foot ankle relative to the drive foot ankle at the initiation of the pitch. A positive or negative stride foot position denoted a closed and open position, respectively. Initiation of the pitch was defined when the center of mass velocity exceeded 1 m/s in the X – direction. Joint forces were calculated using inverse dynamics methods in The MotionMonitor software (Gagnon & Gagnon, 1992). The peak shoulder distraction force during the acceleration phase of the pitch (foot contact to ball release) was normalized to body mass (N/kg) and used for analysis. A Bertec™ force plate (BertecCorp., Columbus, OH, USA) was used to determine the instance of foot contact. Following sensor attachment, participants were given an unlimited amount of time to warm-up their fastball pitch type. Once deemed ready, testing required participants to throw three maximum effort fastball pitches for strikes to a catcher at regulation distance (13.11 m). The average of the three pitches thrown for strikes was used for analysis.
IBM SPSS Statistics 29 (IBM corp., Armonk, NY) was used to perform all statistical analyses. Pearson product-moment correlations were used to examine bivariate associations between stride mechanics (stride length and stride position) and shoulder distraction force. A forward multiple linear regression was used to determine the relationship between stride mechanics and shoulder distraction force. Statistical significance was set a prior to $p < .05$.

RESULTS: Descriptive statistics and bivariate correlations of variables are reported in Table 1 and 2, respectively. Linearity was confirmed by a plot of studentized residuals against the predicted values as well as partial regression plots. The assumption of normality was met by visual inspection of a P-P Plot. Regression analysis revealed a significant and positive relationship between stride length and shoulder distraction force [$R^2 = .11$; $F(1, 61) = 7.345$, $p = .009$], where stride length accounted for 11% of the variation in shoulder distraction force. Shoulder distraction force increased by .94 N/kg for every 10% increase in stride length normalized as a percentage of body height (Table 3). The forward regression analysis excluded stride foot position ($p = .456$).

Table 1. Descriptive statistics presented as mean (standard deviation).

Variable	Mean (SD)
Shoulder Distraction Force (N/kg)	11.7 (3.1)
Stride Mechanics	
Stride Length (%BH)	101.7 (10.8)
Stride Foot Position (m)	-.02 (.2)

Note: %BH = percentage of body height; SD = standard deviation

Table 2. Bivariate correlations of stride mechanics variables and shoulder distraction force.

Variable	Correlation value	p-value
Stride Mechanics		
Stride Length (%BH)	.34	**.009**
Stride Foot Position (m)	-.14	.281

Note: %BH = percentage of body height; bold = statistically significant with p < .05.

Table 3. Multiple regression analysis results.

Shoulder Distraction Force	*β*	*Std. Error*	p-value
Stride Length (%BH)	.094	.035	**.009**

Note: β = unstandardized beta; Std. Error = standard error; bold = statistically significant with p < .05

DISCUSSION: The study aimed to examine the influence of stride mechanics (stride length and stride foot position) on peak shoulder distraction force during the acceleration phase in collegiate softball pitchers. The results showed a positive association between stride length and shoulder distraction force. Specifically, shoulder distraction force increased by .94 N/kg for every 10% increase in stride length normalized as a percentage of body height. A previous examination into the baseball pitch showed there was an association between stride length and increased shoulder kinetics (Fleisig et al., 1995). The current study agrees with those findings, which is not surprising considering it was reported that increased stride length is associated with higher ball velocities, and increased ball velocities are associated with higher shoulder distraction forces during softball pitching (Downs Talmage et al., 2021; Oliver et al., 2018; Werner et al., 2006). Lastly, prior research suggests greater stride lengths are associated with upper extremity pain in collegiate softball pitchers (Oliver et al., 2018, 2019). Therefore, the findings from the current study and prior research collectively suggest that greater stride lengths positively impact pitching performance but may also increase stress at the shoulder and incidence of upper extremity pain. Even so, is important to note stride length in the current study only explained 11% of the variance in shoulder distraction force. Meaning, 89% of the variance was unexplained by stride mechanics. Therefore, it is important to continue investigating other factors that may have a stronger influence on upper extremity stress in softball pitchers.

The lack of association between stride foot position and shoulder distraction force was surprising. This finding disagrees with previous baseball literature concluding that a more open stride position is associated with greater shoulder kinetics and decreased stride length (Fleisig et al., 1995). Baseball literature shows foot position is associated with pelvis and trunk kinematics, and a more open trunk position may cause a decreased shoulder abduction angle before ball release (Lin et al., 2022; O'Holleran et al., 2006). Further, a decreased shoulder abduction angle is related to greater shoulder distraction force in baseball pitching (Manzi et al., 2022; Scarborough et al., 2020). However, the current study reveals that an altered stride foot position may not have the same impact on shoulder stress in softball pitchers as it does in baseball pitching. Thus, it is unknown if the differing mechanics of the trunk and upper extremity during baseball and softball would give insight to the lack of agreement with altered foot placement between the two pitches. Overall, altered stride foot mechanics may influence shoulder kinetics differently based on the difference in baseball and softball pitching mechanics. Therefore, further examination of stride mechanics along with trunk and upper extremity kinematics in relation to shoulder distraction force in softball pitchers is needed.

CONCLUSION: There was a positive relationship between stride length and peak shoulder distraction force during the acceleration phase of the softball pitch. Alternatively, there was not a relationship between stride position and shoulder distraction force. Therefore, coaches should be aware of the potential negative implications of increasing stride length during softball pitching. Although prior research shows greater stride lengths may positively impact performance, this may also increase stress at the shoulder and susceptibility to upper extremity pain.

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