What is the relationship between pitch count, strength, and pain for Division II collegiate softball pitchers?

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Abstract

Collegiate fastpitch softball pitchers utilize an underhand pitching technique which creates high shoulder stress. Injury prevention measures, such as pitch counts, are missing in softball. Higher pitch counts may reduce strength, increase pain, inhibit proper mechanics, and contribute to higher injury risk. Yet, there is a paucity of research exploring monitoring intervention measures within Division II softball pitchers. The purpose of this study was to assess changes in isometric strength, pitch count, self-reported pain, and open and closed kinetic chain functional test performance in Division II softball pitchers at three time points: off-season, pre-season, and in season. Early monitoring strategies indicated reductions in pitching side isometric strength in key muscles that support pitching technique from off-season to pre-season measurements, but in season measurements did not continue this decline. Athletes improved performance in three functional tests but demonstrated reduced muscle endurance of the posterior chain from off-season to pre-season. These patterns continued to be seen during the competitive season.

Review of Literature

Despite the increase in popularity, women's fastpitch softball is relatively understudied compared to its male counterpart, baseball. One of the key differences between the two sports is the style of pitching. In baseball, the pitcher uses an overhand motion to deliver the pitch, while a softball pitcher utilizes an underhand windmill style pitch. Traditionally, the windmill style pitch was thought to be safer and result in less stress at the shoulder, but research has shown that the stresses experienced by a pitcher are similar to those in the overhead pitch of baseball (2, 5-7, 14, 15). These similar stresses are further reflected in the injury rate of the two sports, with softball showing comparable, if not greater rates of injury (5-7, 9, 12). Although the stresses at the shoulder and rates of injury are the same, the protective measures that are seen in baseball, like pitch counts, are not found in fastpitch softball. Moreover, the mechanisms of injury are not as studied and are less understood for the windmill pitch compared to the overhand pitch.

Altered mechanics may put a windmill pitcher at greater risk of injury. While there are many studies that address the mechanics of the windmill style pitch (5-8), very few address differences in mechanics depending on the presence of pain (7, 8). Muscular weakness is another possible source of injury risk, yet there are very few studies that address the strength of a collegiate pitcher (14, 15), and none that look at how the strength values of a pitcher may vary depending on presence of pain. Muscular weakness of key muscles may cause the pitcher to be unable to maintain proper mechanics, resulting in a greater risk of injury.

Like many other aspects of fastpitch softball, mechanisms of injury are also relatively understudied, especially when compared to baseball. Many studies have noted similar if not greater injury rates in softball when compared to baseball (5-7, 9, 12, 15). Studies analyzing data from the NCAA Injury Surveillance program (ISP) have revealed that most pitching injuries are overuse or noncontact, and occur during practice (4, 13). Injuries have also been seen to occur earlier in the season, with one study finding 50% of injuries resulting in time loss of at least two weeks, and no injuries occurring in the last six weeks of the season (12). Although causes cannot be discerned from the results of these studies, there seems to be a possibility that a lack of preseason conditioning may contribute to a higher risk of injury. The current study measures strength and endurance of the upper extremity before and during the competitive season so that changes in these values can be noted.

There may also be a relation between mechanics and injury risk, but it is unclear if altered pitching mechanics cause pain, or if pain causes altered pitching mechanics. Differences in mechanics can be seen when comparing pitchers with and without shoulder pain, which may shed light on possible injury mechanisms (5, 7). Mechanical differences include greater horizontal abduction, greater trunk rotation, and increased stride length in pitchers with shoulder pain, which may be explained by weak shoulder adductors, poor timing, and shifted center of mass respectively, with the former causing increased distraction forces and latter two causing inefficient force transfer (5, 7). Furthermore, pitchers with pain also demonstrate decreased lateral trunk flexion, possibly causing inefficient force transfer. If it is muscle weakness that causes altered mechanics, then the pitcher’s risk of injury can be decreased through strengthening these muscles so that compensations do not have to be made elsewhere along the kinetic chain.

Through electromyography, some studies have identified key musculature used during the windmill pitch, including the gluteus maximus, gluteus medius, supraspinatus, rhomboid, infraspinatus, pectoralis major, teres minor, subscapularis, serratus anterior (3, 9, 10). As previously mentioned, pitchers with pain present greater horizontal abduction of the arm during pitching, which may be caused by weak shoulder adductors, including the pectoralis major (5). The current study measured the strength of pitchers throughout a single season, as well as their pain levels, in an effort to determine whether or not a relationship exists between these two variables.

Despite understanding important musculature used during the windmill pitch, there is a lack of data describing normative strength values for individuals in the population of interest. Of the studies that do exist, the strength of all key musculature identified are not measured, specifically the scapular stabilizers (serratus anterior and rhomboids) (14).

Some of the strength measurements that were taken in the current study have been seen to be associated with injury risk in professional baseball players, but it is unknown if these relationships exist in softball (1). Specifically, external rotation, internal rotation, and supraspinatus strength measurements are associated with likelihood that an athlete will sustain a shoulder injury requiring surgery (1).

Strength decreases have been observed over the course of a single season, but these studies did not keep track of specific pitch count (2, 11, 15). Furthermore, over the course of a single game, multiple games, and multiple days, strength decreases can be observed, as well as increases in pain and fatigue (11). Keeping in mind the key musculature that have been identified, strength deficits of these muscles may hinder a pitcher's ability to maintain proper form and mechanics, increasing her risk of injury.

Problem statement

The relationship between pitch count, strength, and pain of pitchers remains unclear.

Purpose

The purpose of the current study was (i) to assess changes in isometric strength, pitch count, self-reported pain, and open and closed kinetic chain functional test performance in Division II softball pitchers at three time points, (ii) to explore relationships between strength, pitch count, and pain to pilot an athlete monitoring system which could be implemented at additional time points in a competitive season, and (iii) to establish normative data for Division II pitchers.

Research question

The aim of the current study is to answer the central question:

What is the relationship between pitch count, strength, and pain of Division II collegiate softball pitchers?

Hypothesis

I hypothesized that (i) there will be a negative correlation between pitch count and strength, (ii) there will be a positive correlation between pitch count and pain, and (iii) there will be a negative correlation between strength and pain.

Methodology

The current study was a descriptive study in the form of correlational research. The population under study are collegiate softball pitchers. A convenience sample was utilized by recruiting members of Florida Southern's Division II women's softball team who compete as a pitcher (n=6). They must have been injury free within the last six months prior to the beginning of the study. Injury was defined as an injury resulting in time lost from participating in practice or games. Subjects signed an informed consent form prior to taking part in the study. Subjects were excluded if they sustained an injury within the last six months prior to the beginning of the study, or sustained an injury during the study. Subjects who rated their pain within the last 3cm of the 10 cm Visual Analog Scale (VAS) were excluded from the study.

Isometric strength, dynamic strength, shoulder stability, shoulder muscle endurance, and pain was measured at three time points: November 2021, January 2022, and March 2022. Isometric strength was measured using a microFET 2 handheld dynamometer for the following movements: shoulder scaption, shoulder internal rotation, shoulder external rotation, shoulder horizontal adduction, scapular protraction, scapular retraction, hip abduction, and hip extension (see appendix A). Dynamic strength and shoulder stability were assessed using the Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST) (see appendix B), the Upper Quarter Y-balance Test (UQYBT) (see appendix C), and the Seated Shot Put Test (SSPT) (see appendix D). Shoulder muscle endurance was assessed with the Posterior Shoulder Endurance Test (PSET) (see appendix E). Pain was assessed using the 10cm Visual Analog Scale (VAS) (see appendix F). Pitch count data was collected during practices and competitions of the fall 2021 and spring 2022 semesters. Subjects kept track of and reported an estimated number of pitches thrown in practice, as well as participation outside strength training. Pitch count data for pitches thrown in games was gathered using Florida Southern College's Athletics' website.

Internal and External Validity

Possible internal validity threats included if subjects were participating in a strength and conditioning program outside of the study, as this could influence strength and pain values. Furthermore, pitch count data for practices was a self-reported estimation, so data might not accurately reflect exact pitching volumes. To control for instrumentation, the same researcher administered the assessments.

Possible external validity threats included the use of a convenience sample that was too small. The sample only included pitchers from a single team, so it is difficult to generalize results to all Division II softball pitchers.

Data Analysis

Correlations were calculated to determine if there is a relationship between strength and pain, strength and pitch count, and pitch count and pain. The alpha value for the study was set *a priori* as $\alpha < 0.05$.

Results

For off-season and preseason measurements, all participants (n=6) were able to participate in the study. Due to injury resulting in lost practice and/or competition time, three participants were excluded from the study, resulting in only three participants being able to participate in the in season measurements.

From the off season to the preseason, total right side isometric strength (in pounds) across all eight measures decreased (Δ-6.65%). The average right side isometric strength decreased in four of the six upper body assessments: internal rotation (Δ-13%), external rotation (Δ-23%), scapular protraction (Δ-4.5%) and scapular retraction (Δ-9.4%; p=0.035). Right side hip abduction (Δ-10.7%) and hip extension (Δ-14.4%; p=0.011) also decreased. Average total pitch count increased (Δ+3.3%), while the average self-reported pain decreased from 1.11 to 0.71cm (Δ-36%). There were no statistically significant correlations between isometric strength, pitch count, or pain at either time point. Average performance increased in the CKCUEST (Δ+7.7%), SSPT, (Δ+5.4%) and UQYBT (Δ+0.01) while PSET declined (Δ-7.3%) between measures.

Of the three subjects who were able to participate in all three time points, the preseason to the in season, total right side isometric strength (in pounds) across all eight measures increased

(Δ8.50%; $p=0.061$). The average total right side upper body isometric strength, calculated by adding the results of the six upper body assessments, increased (Δ13.16%). The total right side lower body isometric strength, calculated by adding the results of the two lower body assessments, increased for two of the subjects (Δ2.26% and Δ6.47%), but decreased for one (Δ-9.67%). The average right side posterior shoulder endurance test time decreased (Δ-8.47%).

For the in season time point, a positive correlation was found between total pitch count and total right side upper body strength ($p=0.046$; $r=0.997$). No other relationships were found between strength measurements, pitch count, or pain.

For the sake of normative data, the results of the functional tests can be found in tables 1-7.

	Time point		
Subject	Off-season	Preseason	In Season
Subject 1	13.7	15.7	16.3
Subject 2	22	24.3	x
Subject 3	17	18.7	x
Subject 4	15.7	19.3	19.3
Subject 5	17.3	17.3	18
Subject 6	21	20.3	x
Average	17.8	19.3	17.9

Table 1. CKCUEST scores (number of taps).

Note: "x" denotes that the subject did not participate in the test at that time point

Subject	Time point Off-season	Preseason	In Season
Subject 1	147	153	145.7
Subject 2	119.7	132.3	x
Subject 3	128.7	142	x
Subject 4	110.3	125.7	139.7
Subject 5	137.3	116.7	120
Subject 6	123.3	129	x
Average	127.7	133.1	135.1

Table 2. SSPT scores for the right side (inches).

Note: "x" denotes that the subject did not participate in the test at that time point

Subject	Time point Off-season	Preseason	In Season
Subject 1	139.3	140.7	135
Subject 2	122.3	143.3	x
Subject 3	129.3	130.3	x
Subject 4	100.7	111.7	126.3
Subject 5	126	111.7	113.3
Subject 6	133.3	143.7	x
Average	125.2	130.2	124.9

Table 3. SSPT scores for the left side (inches).

Note: "x" denotes that the subject did not participate in the test at that time point

Subject	Time point Off-season	Preseason	In Season
Subject 1	201	184	183.7
Subject 2	193	205.2	x
Subject 3	199.7	210	x
Subject 4	188.3	185.5	205
Subject 5	172	160.8	180
Subject 6	185.8	194.5	x
Average	190	190	189.6

Table 4. UQYBT scores for the right side sum (cm).

Note: "x" denotes that the subject did not participate in the test at that time point

Subject	Time point		
	Off-season	Preseason	In Season
Subject 1	212.7	177.3	179.3
Subject 2	196.8	206.7	x
Subject 3	191.7	190	x
Subject 4	199	186	202
Subject 5	171.3	158	181.7
Subject 6	200	197.5	x
Average	195.3	185.9	187.7

Table 5. UQYBT scores for the left side sum (cm).

Note: "x" denotes that the subject did not participate in the test at that time point

Subject	Time point		
	Off-season	Preseason	In Season
Subject 1	68.7	51	51
Subject 2	73	67	x
Subject 3	75	66	x
Subject 4	85.5	63	60
Subject 5	74.2	92	73
Subject 6	53.6	56	x
Average	71.7	65.8	61.3

Table 6. PSET scores for the right side (seconds).

Note: "x" denotes that the subject did not participate in the test at that time point

Subject	Time point		
	Off-season	Preseason	In Season
Subject 1	70.3	65	54
Subject 2	94	65	x
Subject 3	53	47	x
Subject 4	77.9	65	60
Subject 5	89.4	110	80
Subject 6	53.6	56	x
Average	73	68	64.7

Table 7. PSET scores for the left side (seconds).

Note: "x" denotes that the subject did not participate in the test at that time point

Discussion

There were no relationships between pain and strength or pain and pitch count. It was hypothesized that there would be a relationship between strength and pain, as research has shown that a relationship between pitching mechanics and pain exists (5-7). Since adequate strength must be present in order to maintain proper mechanics, it was hypothesized that decreased strength would be correlated with increased pain, since weak pitchers would not be able to maintain proper mechanics. Although the data does not support this hypothesis, one possible explanation for a lack of relationship is that only one pitcher reported pain during the study. Since a majority of pitchers reported no pain, finding a statistically significant relationship between strength and pain is difficult. Furthermore, research has shown that after a single game and multiple games, pain levels increase (11). The results of the current study did not reflect this finding, as only one subject reported pain, despite all subjects participating in competition. It should be noted that pain measurements were taken after subjects had some recovery time, as opposed to directly after a competition. By allowing subjects time to rest before reporting pain, they may have been able to recover from their outing without significant or noticeable increases in pain.

A positive correlation was found between total right side upper body strength and total pitch count at the in season time point. While this finding goes against the proposed hypotheses, it may be that the pitchers did not reach a large enough pitch volume to see the hypothesized strength decreases. This finding also disagrees with what has been seen in the literature, as research has shown that after a single game and multiple games, strength decreases (11). As previously discussed, strength measurements were taken after subjects had some recovery time, which may explain why strength decreases were not seen, despite time spent pitching in competition.

Decreases were seen in endurance measurements, suggesting the onset of fatigue. Additionally, decreases in lower body strength were seen, specifically from the off season to the preseason. Decreases of both of these measures may suggest an increased injury risk. However, preseason measurements were taken after the subject had winter break, where participation in strength and conditioning programs are not supervised. Therefore, it is possible that some of the subjects were not adhering to their prescribed strength and conditioning programs, resulting in decreased strength. Nonetheless, decreases in these measurements are still noteworthy and should be taken into consideration when creating an athlete monitoring system to evaluate injury risk of these athletes.

With the exception of the PSET, changes in functional tests throughout the course of this study were variable depending on the subject. However, the data collected through this study can be used to begin creating a normative database for this population, so that the sports medicine community can have a better understanding of how these athletes should be performing on these tests.

The most significant limitation of this study was the very small sample size, with an initial sample of six, and only three subjects able to participate in the in season data collection. Due to a small sample size, it is very difficult to reach statistical significance. Off-season measurements were taken after the completion of the fall season, which included some game pitches, while preseason measurements had no game pitches. As discussed, preseason measurements were right after winter break, so athletes may not have been adhering to their strength and conditioning program. Increases in the SSPT and CKCUEST may be explained by the learning effect. Subjects had not previously been exposed to these functional tests, so initial increases from the off-season to the preseason may be explained by the subjects learning how to efficiently perform these tests to achieve better scores.

Future research should repeat this study with more participants and at additional time points (i.e. at the conclusion of the season). Early monitoring strategies should be implemented from the off-season to the preseason, specifically for the lower extremity and endurance, as these measures saw initial decreases during these time points. Endurance training should be incorporated into practice and strength and conditioning programs of pitchers, as well as a focus on unilateral lower extremity stability and strength.

Conclusions

The only relationship found was a positive correlation between total right side upper body strength and pitch count for the in season time point. No relationships were found between other variables, but initial decreases were seen in endurance and total right side lower body strength. Endurance and lower body strength should be monitored, especially early in the season, so that adjustments to pitchers' strength and conditioning programs can address deficits and reduce injury risk. While the current study offers some insight into this population, further research is needed to establish significant trend that can be seen and normative data for Division II softball pitchers.

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Appendix A. Isometric strength tests

Shoulder scaption: The subject will be seated with arm flexed 90° and horizontally abducted 45°. The dynamometer will be placed just proximal to the elbow.

Hip abduction: The subject will be side-lying with leg in slight extension. Hip will be stabilized at the iliac crest. The dynamometer will be placed just proximal to the knee.

Shoulder external rotation: The subject will be supine with arm abducted 45° and elbow flexed 90°. Elbow will be stabilized and the dynamometer will be placed proximal to the wrist on the dorsal side.

Shoulder internal rotation: The subject will be supine with arm abducted 45° and elbow flexed 90°. Elbow will be stabilized and the dynamometer will be placed proximal to the wrist on the palmar side.

Shoulder horizontal adduction: The subject will be seated with arm flexed 90°. The dynamometer will be placed just proximal to the elbow on the bicep.

Scapular protraction: The subject will be seated with arm flexed 90° and elbow flexed 90°. The dynamometer will be placed below the olecranon.

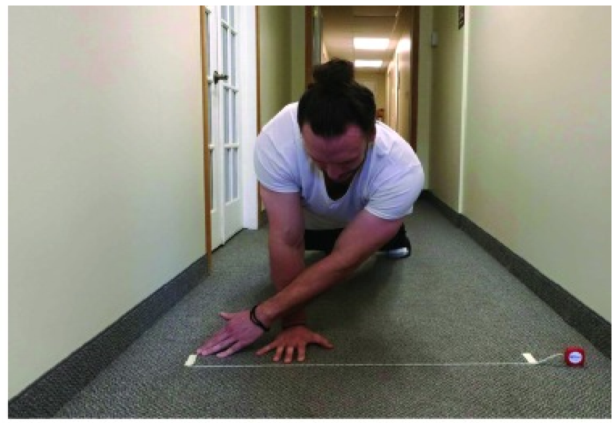
Hip extension: The subject will be prone with knee flexed and hip slightly extended. Bilateral hip will be stabilized at the iliac crest. The dynamometer will be placed just proximal to the knee.

Scapular retraction: The subject will be seated with arm flexed 90° and scapula in a retracted position. Support will be given to the elbow. The dynamometer will be placed on the spine of the scapula.

Appendix B. Closed Kinetic Chain Upper Extremity Stability Test

The subject will begin in a push-up position, with hands below the shoulders. Two tape markers will be 36 inches apart. The subject will alternate tapping the tape lines by reaching across their body. Subjects will attempt to touch the tape as many times as possible in 15 seconds. After a rest, the test will be repeated two more times, for a total of three trials.

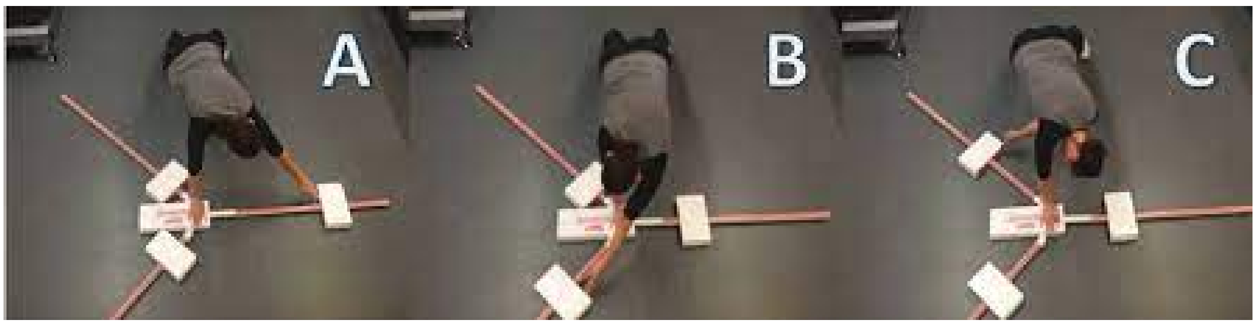
(a)



(b)

Appendix C. Upper Quarter Y-balance Test

The subject will begin in a push-up position. Beginning with either hand, the subject will attempt to reach as far as possible along the three lines. Then the test will be conducted using the other arm.



Appendix D. Seated Shot Put Test

The subject begins in a seated position with their feet flat on the floor and back against the back of the chair. Using a 6 lbs medicine ball, the subject will attempt to put the ball as far as they can. After a rest, the subject will repeat the test two more times, for a total of three times. The subject would repeat the same protocol on the other arm, again for a total of three maximal puts.

Appendix E. Posterior Shoulder Endurance Test

The subject will begin in a prone position. While holding a weight equal to about 2% of the subject's body weight (3 lbs or 4 lbs), the subject will lift their arm so that it is parallel to the ground and lower their arm so that it is perpendicular to the ground, in time with a metronome set at 60 bpm. The subject will attempt to perform as many repetitions as possible. The test ends when the subject voluntarily ends the test, the subject is no longer able to achieve the proper position, the subject can no longer keep time with the metronome, or the subject uses excessive trunk rotation to achieve the proper position.

Appendix F. 10cm Visual Analog Scale