Published in final edited form as:

Am J Sports Med. 2017 May ; 45(6): 1413–1419. doi:10.1177/0363546516688657.

Effect of pitching consecutive days in youth softball tournaments on objective shoulder strength and subjective shoulder symptoms

S. Andrew Skillington, BA¹, Robert H. Brophy, MD², Rick W. Wright, MD², and Matthew V. Smith, MD²

¹Washington University in St Louis School of Medicine, St Louis, Missouri, USA

²Department of Orthopedics, Washington University in St Louis School of Medicine, St Louis, Missouri, USA

Abstract

Background—The windmill pitching motion has been associated with risk for shoulder injury. Since there are no pitching limits on youth fast-pitch softball pitchers, these athletes often pitch multiple games across consecutive days. Strength changes, fatigue levels, and shoulder pain that develop among female fast-pitch pitchers over the course of consecutive days of pitching have not been investigated.

Hypothesis—Over the course of 2 and 3-day fast-pitch softball tournaments, pitchers will develop progressive objective weakness and increased subjective shoulder fatigue and pain without complete recovery between days.

Study Design—Cross-Sectional Study.

Methods—Female fast-pitch softball pitchers between the ages of 14 and 18 who were pitching in 2 and 3-day tournaments were recruited for study participation. At the beginning and end of each day of tournament play, pitchers were asked to quantify shoulder fatigue and shoulder pain levels of their dominant throwing arm using a 10-point visual analog scale (VAS). Shoulder abduction, flexion, external rotation, internal rotation, elbow flexion, and elbow extension strength measurements were gathered using a hand-held dynamometer.

Results—Over the course of an average single day of tournament participation, pitchers developed significant increases in VAS shoulder fatigue (2.0, 95% CI: 1.3 to 3.0), and pain (1.3, 95% CI: 0.5 to 2.3) and significant strength loss in all tested motions. Pitchers also developed significant increases in VAS shoulder fatigue (3.5, 95% CI: 1.5 to 5.5), VAS shoulder pain (2.5, 95% CI: 1.0 to 4.5) and strength loss in all tested motions over the entire tournament. Shoulder pain, fatigue, and strength do not fully recover between days. The accumulation of subjective shoulder pain and fatigue over the course of tournament play were closely correlated.

Conclusion—Among youth female fast-pitch softball pitchers, there is a progressive increase in shoulder fatigue, pain, and weakness over the course of 2 and 3-day tournaments without full recovery between consecutive days pitching.

Key Terms

Softball; Fast-Pitch; Tournament; Female Athlete

Introduction

Fast-pitch softball is one of the most popular and fastest growing sports among youth females^{10,12}. The number of high school softball players in the US is nearing that of baseball¹. The biomechanics of the traditional overhand pitch in baseball have been studied extensively and the injury risk due to overuse and fatigue has been well documented^{5,7-9,21,23,28}. In contrast, there is a relative paucity of research regarding biomechanics and injury risk related to the windmill pitch used in fast-pitch softball, potentially due to the perception that it is safer than the overhead pitch.

Biomechanical analyses of the windmill pitch show that the stress placed on the shoulder is similar to that seen with the overhead pitch^{3,6,22,29}. Additionally, clinical studies have shown that the injury incidence in fast-pitch softball pitchers is substantial^{18,25,26}. Studies such as these highlight the high prevalence of injury among fast-pitch softball pitchers, yet the incidence of injury, types of injury, and mechanisms of injury among these athletes remain poorly documented. Despite the growing evidence that the windmill pitching motion is not as safe as previously thought, there are no pitching limitations established in fast-pitch softball like there are in baseball²⁴. Currently, a single pitcher may pitch multiple games in a single day for 2–3 days in a row, particularly in youth select-level tournaments.

There have been no previous studies to determine changes in strength, fatigue and pain related to real-game windmill pitching. Additionally, the timetable for resolution of strength deficits seen after a single day pitching is unknown. The purpose of this study was to quantify the objective strength changes and the subjective shoulder fatigue and pain levels in fast-pitch softball pitchers during 2 to 3 consecutive days of pitching. Our hypothesis was that, over the course of 2 and 3-day fast-pitch softball tournaments, pitchers will develop progressive objective weakness, along with increased subjective shoulder fatigue and pain without complete recovery between days pitching.

Methods

Subjects and Study Design

Institutional review board (IRB) approval was obtained prior to the initiation of the study. Over a two-month study period, data was collected on 17 female fast-pitch softball pitchers between the ages of 14 and 18 years who were participating in 2-day and 3-day weekend tournaments hosted either by the Amateur Softball Association (ASA) or the United States Specialty Sports Association (USSSA). Pitchers and their legal guardians provided informed consent at the start of the tournament prior to participation in the study. Pitchers who were not scheduled to pitch every day of the tournament were excluded. Three pitchers were lost to follow-up after a single day of tournament play and were excluded from the analysis. One

pitcher chose to exit the study and 2 pitchers were lost to follow-up after the tournament was cancelled due to weather. Thus, 14 pitchers were included in the final data analysis.

Data Collection

Upon entering the study, pitchers provided information on their demographics, softball history, and health history. Demographic data included age, race, height, weight, and hand dominance. Softball history included years of experience playing softball, years of experience pitching, months of the year participating in softball-related activities, average number of games pitched per week, highest level of competition, current amount of pitching instruction, types of pitches thrown, and other positions played besides pitcher. Health history included history of shoulder injury, history of shoulder pain, history of any major medical problems, and data on nutrition, bone health, and women's health. Additionally, a Shoulder Activity Score⁴ was recorded.

At the start and end of each day of tournament play, pitchers were assessed for fatigue, pain, and strength in the dominant throwing shoulder. Shoulder fatigue and pain were self-reported using a previously validated visual analog scale (VAS)^{13,17,20}. Subjects were asked to rate their shoulder fatigue and pain from 0 to 10 with 0 being no shoulder fatigue/pain and 10 being the worst imaginable shoulder fatigue/pain.

Shoulder strength was objectively assessed using a handheld dynamometer (microFET3, Hoggan Health Industries, West Jordan, UT) by a single trained examiner to eliminate measurement bias. Supraspinatus strength was measured in Jobe's position with the arm abducted 90° in the scapular plane and in full internal rotation¹⁴. Shoulder forward flexion strength was assessed in Speed's position at 90° of shoulder flexion with the elbow fully extended and forearm fully supinated. External rotation strength was tested in three positions as described by Kelly et al¹⁵. With the elbow flexed 90° and forearm held in neutral rotation, external rotation strength was assessed first in 0° abduction and 0° rotation, second in 90° abduction and 0° rotation, and finally in 90° abduction and 90° external rotation¹⁵. Internal rotation strength was tested in two positions as described by Hayes et al¹¹. Internal rotation strength was assessed first with the elbow flexed 90° and shoulder abducted 90° in 0° rotation and second using the hand behind back lift-off test¹¹. Finally, elbow flexion and extension strength were measured with the arm held by the side, elbow flexed 90°, and forearm supinated for assessing flexion and pronated for assessing extension. For all strength measurements, the dynamometer was set to the high sensitivity setting and placed on the distal third of the forearm just proximal to the wrist¹¹. Each measurement was repeated three times with high reproducibility, and the median value of kilograms of force was used for data analysis. Evaluation of shoulder fatigue, pain, and strength was assessed in a standardized fashion by a single study author (S.A.S.). For each day of tournament play, the number of games played, the number of games pitched, the number of innings pitched, and the number of pitches thrown were recorded.

Statistical Analysis

A power analysis for non-parametric, paired data was performed with a two-sided alpha level of 0.05 and a power of 80% to detect a difference of 2 on the visual analog scale for

fatigue and pain. A difference of 2 was chosen because this represents the minimal difference that is clinically significant²⁷. Using this effect size, 16 subjects were required for the study. The visual analog scale was used for the power analysis rather than objective strength measures because clinically-meaningful differences in VAS scores have been established, but the degree of strength loss that is clinically significant or the single strength measure that is most relevant among fast-pitch softball pitchers is unknown. Standard descriptive statistics were used to describe the cohort. Wilcoxon-signed rank test was used to compare differences in shoulder fatigue, shoulder pain, and strength before and after an average single day of tournament play and before and after an entire tournament. Additionally, Wilcoxon signed-rank test was used to compare tournament and single day differences in shoulder fatigue, shoulder pain, and strength as well as differences between initial and final baseline measures. For these analyses, the estimated median differences with 95% confidence intervals (95% CI) were reported. Spearman's rho analysis was used to quantify the correlation between shoulder fatigue and shoulder pain and to evaluate the relationship between pitching exposure and subsequent shoulder fatigue and pain. Simple linear regression analyses were conducted to evaluate the relationships between the independent variables age, body mass index (BMI), years of pitching experience, extent of pitching instruction received, and history of shoulder pain or shoulder injury and the dependent variables shoulder fatigue, shoulder pain, and strength loss over the course of weekend tournaments. All tests of statistical significance were evaluated at the two-sided alpha level of 0.05. Statistical analyses were conducted using SPSS statistical software version 22.0 (SPSS Inc., Chicago, IL) and Minitab 17 (Minitab Inc., State College, PA).

Results

Eight pitchers participated in 3-day tournaments and 6 pitchers participated in 2-day tournaments. These athletes had a median age of 16.5 years and median pitching experience of 8 years (Table 1). Athletes pitched in 1.5 games per day and threw 82 pitches per day with a total exposure of 3.0 games pitched and 166 pitches thrown per tournament (Table 2).

Over the course of an average single day of tournament participation, pitchers had a significant increase in shoulder fatigue and shoulder pain. On a visual analog scale, pitchers' shoulder pain increased by 1.3 (95% CI, 0.5 to 2.3) and shoulder fatigue increased by 2.0 (95% CI, 1.3 to 3.0). Additionally, over the course of an average single day of tournament participation, pitchers lost a significant amount of strength in 7 of 9 tests conducted (Table 3).

Over the course of an entire tournament, pitchers reported an increase in shoulder pain of 2.5 (95% CI, 1.0 to 4.5) and shoulder fatigue of 3.5 (95% CI, 1.5 to 5.5) on a visual analog scale compared to baseline values at the start of the tournament. Also, pitchers demonstrated a decrease in strength over the course of an entire tournament in 8 of 9 tests conducted with only external rotation in adduction failing to reach statistical significance (Table 3). Additionally, pitchers developed significantly more shoulder pain, shoulder fatigue, and weakness over the course of an entire tournament than over the course of an average single day of tournament participation (Table 4).

In an analysis comparing the baseline measurements starting the first tournament day to the baseline measurements starting the final tournament day, there was a significant increase in shoulder pain (difference of 1.0 [95% CI, 0.0 to 2.0]) and shoulder fatigue (difference of 2.0 [95% CI, 0.5 to 3.5]) and a significant decrease in strength in 8 of 9 tests conducted with only external rotation in adduction failing to reach statistical significance (Table 4). The increase in subjective shoulder pain and fatigue and concomitant decrease in strength over the course of 2-day and 3-day tournaments is shown in Figures 1 and 2 respectively. These figures illustrate the progressive increase in shoulder pain and fatigue and decrease in strength from the start of tournament play on Friday to the end of tournament play on Sunday. As can be seen, shoulder pain, fatigue, and strength do not fully recover between days. Additionally, the accumulation of subjective shoulder pain and fatigue over the course of tournament play were closely correlated (Spearman's $\rho = 0.74$, $p < 0.001$).

Spearman's ρ analyses did not show a relationship between pitching exposure and the development of shoulder fatigue and pain. There was no correlation between total pitches thrown, total innings pitched, or games pitched with any of the subjective or objective outcome measures.

In simple linear regression analyses assessing the relationships between age, BMI, years of pitching experience, extent of pitching instruction received, and history of shoulder pain or injury with the development of shoulder pain, fatigue, or strength loss there were no significant associations detected. Older pitchers, pitchers with more years of experience, and pitchers with a higher BMI tended to develop more shoulder pain and fatigue over the course of a tournament, but these associations did not reach statistical significance.

Discussion

This study is the first to quantify changes in fatigue, pain, and strength that occur in the upper extremity in fast-pitch softball pitchers over consecutive days pitching. Two and three-day tournaments are commonplace in youth fast-pitch softball with teams often using the same pitcher throughout the tournament. Our data clearly show that shoulder and elbow strength decline after a single day of competitive windmill pitching and continue to decline over consecutive days of pitching. We also show that there are significant increases in subjective measures of shoulder fatigue and pain coinciding with this decline in strength. Importantly, pitchers did not recover to their baseline strength in many of the tested muscle groups by the day following pitching indicating that there was an inadequate period of rest. This may account for the increase in pain experienced over the course of the tournament as tissue damage can occur in fatigued muscles². Interestingly, we did not identify a dose-response relationship between pitching exposure and the development of fatigue and pain. It is possible that pitchers who pitched more had better fitness and were thus less likely to develop substantial pain and fatigue.

Prior biomechanical studies have demonstrated the high forces and torques generated at the shoulder and elbow during the windmill pitching motion. During the delivery phase of the windmill motion, peak compressive forces at the shoulder and elbow of 98% and 70% body weight respectively have been demonstrated³. The greatest torques at the shoulder generated

during the windmill motion include abduction, internal rotation, and extension³. Additionally, at the elbow, significant flexion torque is required to control elbow extension and initiate elbow flexion³. In the present study, the greatest strength changes were seen in shoulder abduction, flexion, internal rotation, elbow flexion, and elbow extension. Fatigue and strength loss of these muscle groups coincide with the demands placed on the upper extremity during the windmill pitching motion. In contrast, external rotation strength deficits were minimal in this study. External rotation was tested in 3 positions, and external rotation weakness was not consistently demonstrated in any single position. Numerous analyses showed strength changes in external rotation; however, the 95% confidence intervals surrounding these differences were wide indicating the variability in strength loss among pitchers. Additionally, some of the statistically significant strength changes in external rotation were small and thus may not have been clinically significant. During the delivery phase of the windmill motion, at or just prior to ball release, there is a forceful deceleration of the arm. Maffett et al showed that teres minor is active in this deceleration of the humerus, but they concluded that there is reduced stress placed on teres minor because of the dissipation of force as the arm contacts the lateral thigh¹⁹. It is possible that the variability in external rotation weakness observed in our cohort may be due to variability in technique as the arm is decelerated during release of the ball.

It is possible that the subjective and objective fatigue and strength loss experienced by fast-pitch softball pitchers over the course of single and multiple consecutive days pitching may predispose to injury. In baseball, fatigue has been identified as one of the most significant risk factors for injury and the need for surgery^{7,16}. Mullaney et al observed fatigue patterns in baseball pitchers similar to those seen in the fast-pitch softball pitchers in our study²¹. Murray et al showed that perceived fatigue reported during actual games in seven major league baseball pitchers correlated to significant changes in body kinematics during throwing²⁸. Likewise, the fatigue patterns seen in our study may result in compensatory changes in pitching mechanics that place additional stress on the upper extremity and may increase the risk for injury. Further research is needed to determine what fatigue-related compensatory changes occur in fast-pitch pitching kinematics. Furthermore, future research is necessary to determine the degree of strength loss required for compensatory changes to occur. The extent of strength loss that is clinically-meaningful among fast-pitch pitchers is not currently known. Additionally, future research may clarify the relationship between upper extremity fatigue, strength loss, and subsequent shoulder injury.

Our study has a number of limitations, including the small sample size, drop out, and variability in the number of days played. We enrolled 17 subjects initially, meeting our power analysis target of 16. Although 3 subjects dropped out, the retention rate of 82% meets most standards for clinical investigations. Despite falling slightly below our power analysis target, the subjective measures of fatigue and pain and the objective strength measurements all showed statistically- and clinically-significant differences. Since our VAS scores were more precise than the power analysis presumed, the study was adequately powered despite the dropout. With regards to variability in the number of days played, regardless of whether the athlete participated in 2- or 3-day tournaments, the same trend of increasing pain and fatigue without full recovery between days was observed. This cross-sectional assessment of pitchers in the mid to late part of the 3 to 4-month season may have

included pitchers who were more prone to fatigue due to the cumulative effects of pitching through the season. Conversely, the pitchers may have been more conditioned at this point in the season and subsequently less prone to fatigue. Repeated assessment of the same pitchers throughout a season would help determine if pitchers were more easily fatigued in the beginning, middle or end of the season. Smith et al showed that the majority of pitching injuries occur in the first 6 weeks of the season²⁶. Therefore, our study may have included a disproportionate number of healthy pitchers who had avoided early-season injuries. A larger sample of pitchers over a broader cross section of the season would help increase the precision of our results and better model what risk factors contribute to fatigue and pain related to pitching.

Conclusion

There was a progressive increase in subjective shoulder fatigue and pain coinciding with a decrease in objective strength measures over the course of female fast-pitch softball tournaments. Pitchers developed significant shoulder fatigue and pain, and upper extremity weakness, without adequate recovery between consecutive days pitching. The shoulder fatigue and weakness that accumulates with consecutive days pitching may predispose to injury. Further research is needed to identify and characterize risk factors for shoulder fatigue, weakness and pain and their association with subsequent risk for injury among fast-pitch softball pitchers.

Acknowledgments

This publication was supported by the National Heart, Lung, and Blood Institute grant T35HL007815. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

References

1. [Accessed April 18, 2016] 2014–2015 High School Athletics Participation Survey. http://www.nfhs.org/ParticipationStatics/PDF/2014-15_Participation_Survey_Results.pdf
2. Allen DG. Skeletal muscle function: role of ionic changes in fatigue, damage and disease. *Clin Exp Pharmacol Physiol*. 2004; 31(8):485–493.
3. Barrentine SW, Fleisig GS, Whiteside JA, Escamilla RF, Andrews JR. Biomechanics of windmill softball pitching with implications about injury mechanisms at the shoulder and elbow. *J Orthop Sports Phys Ther*. 1998; 28(6):405–415. [PubMed: 9836172]
4. Brophy RH, Beauvais RL, Jones EC, Cordasco FA, Marx RG. Measurement of shoulder activity level. *Clin Orthop Relat Res*. 2005; 439:101–108. [PubMed: 16205147]
5. Davis JT, Limpisvasti O, Fluhme D, et al. The effect of pitching biomechanics on the upper extremity in youth and adolescent baseball pitchers. *Am J Sports Med*. 2009; 37(8):1484–1491. [PubMed: 19633301]
6. Doyle FM. Review of the windmill pitch: biomechanics and injuries. *J Chiropr Med*. 2004; 3(2):53–62. [PubMed: 19674624]
7. Escamilla RF, Barrentine SW, Fleisig GS, et al. Pitching biomechanics as a pitcher approaches muscular fatigue during a simulated baseball game. *Am J Sports Med*. 2007; 35(1):23–33. [PubMed: 16973902]
8. Fleisig GS, Andrews JR, Dillman CJ, Escamilla RF. Kinetics of baseball pitching with implications about injury mechanisms. *Am J Sports Med*. 1995; 23(2):233–239. [PubMed: 7778711]

9. Fleisig GS, Barrentine SW, Zheng N, Escamilla RF, Andrews JR. Kinematic and kinetic comparison of baseball pitching among various levels of development. *J Biomech.* 1999; 32(12):1371–1375. [PubMed: 10569718]
10. Flynn M. Softball slides into the 21st Century: growth in popularity of softball in schools. *Parks & Recreation.* 1995; 30(4):36.
11. Hayes K, Walton JR, Szomor ZL, Murrell GA. Reliability of 3 methods for assessing shoulder strength. *J Shoulder Elbow Surg.* 2002; 11(1):33–39. [PubMed: 11845146]
12. Hughes, A. [Accessed September 23, 2016] Softball popularity continues to grow: Popularity and exposure may aid in Olympics addition. <http://www.ncaa.com/news/softball/2011-07-23/softball-popularity-continues-grow>
13. Huskisson EC. Measurement of pain. *J Rheumatol.* 1982; 9(5):768–769. [PubMed: 6184474]
14. Jobe FW, Moynes DR. Delineation of diagnostic criteria and a rehabilitation program for rotator cuff injuries. *Am J Sports Med.* 1982; 10(6):336–339. [PubMed: 7180952]
15. Kelly BT, Kadrmaz WR, Speer KP. The manual muscle examination for rotator cuff strength. An electromyographic investigation. *Am J Sports Med.* 1996; 24(5):581–588. [PubMed: 8883676]
16. Kerut EK, Kerut DG, Fleisig GS, Andrews JR. Prevention of arm injury in youth baseball pitchers. *J La State Med Soc.* 2008; 160(2):95–98. [PubMed: 18681352]
17. Lee KA, Hicks G, Nino-Murcia G. Validity and reliability of a scale to assess fatigue. *Psychiatry Res.* 1991; 36(3):291–298. [PubMed: 2062970]
18. Loosli AR, Requa RK, Garrick JG, Hanley E. Injuries to pitchers in women's collegiate fast-pitch softball. *Am J Sports Med.* 1992; 20(1):35–37. [PubMed: 1554071]
19. Maffet MW, Jobe FW, Pink MM, Brault J, Mathiyakom W. Shoulder muscle firing patterns during the windmill softball pitch. *Am J Sports Med.* 1997; 25(3):369–374. [PubMed: 9167819]
20. McCormack HM, Horne DJ, Sheather S. Clinical applications of visual analogue scales: a critical review. *Psychol Med.* 1988; 18(4):1007–1019. [PubMed: 3078045]
21. Mullaney MJ, McHugh MP, Donofrio TM, Nicholas SJ. Upper and lower extremity muscle fatigue after a baseball pitching performance. *Am J Sports Med.* 2005; 33(1):108–113. [PubMed: 15611006]
22. Oliver GD, Plummer HA, Keeley DW. Muscle activation patterns of the upper and lower extremity during the windmill softball pitch. *J Strength Cond Res.* 2011; 25(6):1653–1658. [PubMed: 21358429]
23. Olsen SJ 2nd, Fleisig GS, Dun S, Loftice J, Andrews JR. Risk factors for shoulder and elbow injuries in adolescent baseball pitchers. *Am J Sports Med.* 2006; 34(6):905–912. [PubMed: 16452269]
24. Petty DH, Andrews JR, Fleisig GS, Cain EL. Ulnar collateral ligament reconstruction in high school baseball players: clinical results and injury risk factors. *Am J Sports Med.* 2004; 32(5):1158–1164. [PubMed: 15262637]
25. Powell JW, Barber-Foss KD. Injury patterns in selected high school sports: a review of the 1995–1997 seasons. *J Athl Train.* 1999; 34(3):277–284. [PubMed: 16558577]
26. Smith MV, Davis R, Brophy RH, Prather H, Garbutt J, Wright RW. Prospective Player-Reported Injuries in Female Youth Fast-Pitch Softball Players. *Sports health.* 2015; 7(6):497–503. [PubMed: 26502442]
27. Todd KH, Funk KG, Funk JP, Bonacci R. Clinical significance of reported changes in pain severity. *Ann Emerg Med.* 1996; 27(4):485–489. [PubMed: 8604867]
28. Werner SL, Gill TJ, Murray TA, Cook TD, Hawkins RJ. Relationships between throwing mechanics and shoulder distraction in professional baseball pitchers. *Am J Sports Med.* 2001; 29(3):354–358. [PubMed: 11394608]
29. Werner SL, Guido JA, McNeice RP, Richardson JL, Delude NA, Stewart GW. Biomechanics of youth windmill softball pitching. *Am J Sports Med.* 2005; 33(4):552–560. [PubMed: 15722291]

What is known about the subject

Biomechanical analyses have reported the high level of stress placed on the shoulder during the windmill pitching motion used in fast-pitch softball. Clinical studies have shown that there is a high incidence of shoulder injury among youth female fast-pitch softball pitchers.

What this study adds to existing knowledge

To our knowledge, this is the first study to investigate shoulder fatigue, pain, and strength changes associated with real-game windmill pitching. This study provides insight into how the shoulder musculature fatigues over the course of a single day and multiple consecutive days of windmill pitching. Furthermore, this study demonstrates that there is an inadequate recovery period between consecutive days pitching for youth female fast-pitch softball pitchers at weekend tournaments.

Figure 1.
Subjective Shoulder Fatigue and Pain Changes over the Course of Weekend Tournaments
Abbreviations: Fri, Friday; Sat, Saturday; Sun, Sunday

A

B

Figure 2.
Upper Extremity Strength Changes over the Course of Weekend Tournaments

Abbreviations: ER, external rotation; IR, internal rotation; Fri, Friday; Sat, Saturday; Sun, Sunday Elbow flexion/extension and shoulder flexion/abduction are represented in 2A. Shoulder internal and external rotation are represented in 2B.

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Table 1

Characteristics of the Cohort

Characteristic	Total Cohort n=14
Age, Years	
Median (Range)	16.5 (14 to 18)
Height, Centimeters	
Median (Range)	171 (157 to 183)
Weight, Kilograms	
Median (Range)	66.5 (50.8 to 81.6)
Body Mass Index	
Median (Range)	23 (18 to 27)
Pitching Experience, Years	
Median (Range)	8 (4 to 11)
Highest Level of Competition	
High School	3 (21%)
Select Club	11 (79%)
Pitching Instruction	
Not Regularly	2 (15%)
Monthly	1 (8%)
Weekly	8 (62%)
More Than Once Weekly	2 (15%)
History of Shoulder Pain	
No	9 (64%)
Yes	5 (36%)
History of Shoulder Injury	
No	10 (71%)
Yes	4 (29%)

Table 2

Average Pitcher's Experience at Weekend Tournaments

	Median Value (Range)
Single Day	
Games Played	2.4 (1.0 to 4.0)
Games Pitched	1.5 (1.0 to 3.0)
Innings Pitched	6.0 (2.7 to 11.3)
Total Pitches	82 (41 to 191)
Tournament	
Games Played	5.0 (2.0 to 7.0)
Games Pitched	3.0 (2.0 to 6.0)
Innings Pitched	12.0 (7.0 to 23.7)
Total Pitches	166 (95 to 381)

Table 3
Accumulation of Shoulder Pain, Shoulder Fatigue, and Weakness over the Course of Weekend Tournaments

	Start of Day	End of Day	Difference (95% CI)	P Value	Start of Tournament	End of Tournament	Difference (95% CI)	P Value
Subjective Pain and Fatigue								
Shoulder Pain	1.0	2.6	1.3 (0.5 to 2.3)	0.004	0.0	3.0	2.5 (1.0 to 4.5)	0.009
Shoulder Fatigue	2.3	4.4	2.0 (1.3 to 3.0)	0.002	0.5	4.5	3.5 (1.5 to 5.5)	0.01
Strength								
Shoulder Abduction	5.9	5.3	0.8 (0.3 to 1.2)	0.005	5.9	5.1	1.0 (0.4 to 1.6)	0.01
Shoulder Flexion	6.7	5.9	0.8 (0.2 to 1.0)	0.01	6.9	5.5	1.3 (0.5 to 1.9)	0.009
ER in Adduction	6.5	5.9	0.4 (0.1 to 0.7)	0.05	6.3	5.2	0.6 (−0.2 to 1.4)	0.16
ER in 90° Abduction at 0° ER	6.8	6.1	0.9 (0.4 to 1.4)	0.003	7.0	5.7	1.4 (0.6 to 2.2)	0.009
ER in 90° Abduction at 90° ER	4.2	4.2	0.1 (−0.2 to 0.4)	0.36	4.3	4.0	0.5 (0.1 to 1.0)	0.03
IR in 90° Abduction	8.8	8.2	0.6 (0.3 to 0.8)	0.003	9.0	8.0	0.9 (0.5 to 1.3)	0.003
Lift-Off Test	4.5	4.4	0.3 (0.0 to 0.8)	0.07	5.1	4.0	0.9 (0.4 to 1.5)	0.009
Elbow Flexion	13.5	11.2	1.7 (0.8 to 2.7)	0.003	14.4	9.5	3.5 (2.1 to 4.9)	0.003
Elbow Extension	11.2	10.2	0.7 (0.1 to 1.5)	0.03	12.3	8.7	2.5 (1.6 to 3.3)	0.003

Abbreviations: CI, confidence interval; ER, external rotation; IR, internal rotation

Shoulder pain and fatigue were measured using visual analog scales from 0 to 10 with median values presented. Strength was measured in kilograms of force with median values presented. All differences are estimated median differences with associated 95% confidence intervals.

Table 4
Shoulder Pain, Shoulder Fatigue, and Strength Comparison of Tournament and Single Day Differences; Comparison of Baseline Values

	Single Day Difference	Tournament Difference	Difference (95% CI)	P Value	Initial Baseline	Final Baseline	Difference (95% CI)	P Value
Subjective Pain and Fatigue								
Shoulder Pain	1.2	2.0	1.2 (0.4 to 2.1)	0.01	0.0	2.0	1.0 (0.0 to 2.0)	0.04
Shoulder Fatigue	2.0	4.0	1.8 (0.5 to 2.4)	0.05	1.0	3.0	2.0 (0.5 to 3.5)	0.04
Strength								
Shoulder Abduction	0.8	1.0	0.3 (0.2 to 0.6)	0.02	6.1	5.6	0.6 (0.3 to 1.0)	0.007
Shoulder Flexion	0.9	1.5	0.5 (0.3 to 1.0)	0.005	6.9	5.9	1.1 (0.5 to 1.7)	0.005
ER in Adduction	0.5	0.5	0.3 (-0.4 to 0.9)	0.33	6.5	6.0	0.1 (-0.6 to 0.9)	0.83
ER in 90° Abduction at 0° ER	0.8	1.5	0.5 (-0.1 to 1.2)	0.17	7.4	6.5	1.1 (0.2 to 1.8)	0.02
ER in 90° Abduction at 90° ER	0.1	0.5	0.6 (0.2 to 1.0)	0.01	4.5	4.2	0.5 (0.0 to 0.9)	0.05
IR in 90° Abduction	0.7	0.9	0.4 (0.0 to 0.8)	0.05	9.0	8.7	0.6 (0.3 to 1.0)	0.004
Lift-Off Test	0.3	1.0	0.6 (0.3 to 1.0)	0.004	5.1	4.3	0.7 (0.3 to 1.2)	0.002
Elbow Flexion	1.7	3.2	1.9 (1.3 to 2.8)	0.003	14.4	11.6	2.2 (1.2 to 3.4)	0.002
Elbow Extension	0.7	2.5	2.0 (1.2 to 2.5)	0.003	12.3	10.2	2.0 (1.2 to 2.7)	0.002

Abbreviations: CI, confidence interval; ER, external rotation; IR, internal rotation

Shoulder pain and fatigue were measured using visual analog scales from 0 to 10 with median values presented. Strength was measured in kilograms of force with median values presented. All differences are estimated median differences with associated 95% confidence intervals.