THE EFFECTS OF FATIGUE ON SOFTBALL PITCHER FROM PITCHING MULTIPLE GAMES

Tom Wu, Christine Semler, Pamela J. Russell and Tsung-Lin Lu

Department of Movement Arts, Health Promotion and Leisure Studies, Bridgewater State University, Bridgewater, United States

The purpose of this study was to examine the effects of fatigue on softball pitching from pitching back to back games. Players were asked to throw 15 balls in each inning for seven innings and for a total of two games. The results showed fastball's velocity in the first inning of the first game (25.4 ± 2.5 m/s) had significantly decreased after a game and a half (24.3 ± 2.7 m/s; p = 0.00). Hence, this study suggests that the pitchers started to show signs of fatigue after this amount of pitches (165 pitches), so softball coaches may take this into consideration and make necessary pitching change. Given the established relationship between fatigue and injury in pitchers, the Amateur Softball Association may use this information to implement a pitch count to protect softball pitchers from overuse injury.

KEYWORDS: fatigue, pitching, softball, windmill.

INTRODUCTION: Softball is a fast growing sport worldwide. The Amateur Softball Association (ASA) reports that over 80,000 teams, 1.3 million players and 300,000 coaches participate in USA youth softball annually (*"USA Softball",* 2017). Loosli, Requa, Garrick and Hanley (1992) indicated that college softball pitchers have reported a 45% (11/24) incident of time-loss injuries in a single season, and these injuries were primarily bicipital and rotator cuff tendinitis and strain at shoulder and elbow joints. The bicipital and rotator cuff injuries are prime examples of overuse injury in softball (Maffet et al., 1997). Similarly, Hill, Humphries, Weidner and Newton (2004) surveyed 181 NCAA female pitchers and 25% of their injuries were at the shoulder joint due to overuse. Recently, Smith, Davis, Brophy, Prather, Garbutt and Wright (2015) evaluated injury rates on youth female softball players with the study showing 18 reported injuries by 48 pitchers (38%) attributed to pitching and 11 of these injuries (61%) occurred at the shoulder joint. Further, Werner, Guido, McNeice, Richardson, Delude and Stewart (2005) found that young female softball pitchers experienced the same amount of loads and stress in their shoulder and elbow joints as baseball pitchers and college softball pitchers. The authors further indicated that a typical softball pitcher may throw between 1,200 to1,500 pitches in a three-day weekend tournament. Marshall, Hamstra-Wright, Dick, Grove and Agel (2007) have reported that out of all positions played on a softball team, the pitcher has the highest prevalence of injury which accounts for 10.8% of injuries. Most pitching injuries are the result of cumulative microtrauma due to repetition of the pitching motion in the shoulder and elbow joints (Fleisig, 1994). Pitchers are required to throw the ball with the maximum velocity and, if not, with the maximum spin on the ball in attempt to alter the ball's trajectory. This creates a substantial amount of force and torque acting on body joints, and without proper pitching mechanics and sufficient rest, an injury may occur. Corben, Cerrone, Soviero, Kwiecien, Nicholas, and McHugh (2015) conducted a comprehensive study on muscle fatigue in softball pitching and found a small loss of pitching velocity from the first to last inning; nevertheless, a profound bilateral fatigue was observed in the shoulder's scapula tests and with more selective fatigue in the shoulder and arm muscles. In youth baseball, pitchers are limited to a maximum of 210 pitches per week to prevent pitching fatigue and overuse injuries (Lyman et al, 2002). For the same reasons in baseball to prevent overuse pitching injuries from fatigue, Postlmayr, Wu and Ashely (2012) and Ashley, Wu and Postlmaryr (2012) conducted studies to establish a pitch count for softball pitchers, and the results showed no change in the kinematics of softball pitching over a range of 70 fastball pitches in a game, but a trend of decreased ball velocity was observed. These studies concluded that softball pitchers are capable of pitching an entire game with approximately 70 pitches. However, these studies were limited to 70 pitches of fastball only, but in a game of softball, pitchers throw a variety of pitches in an inning which may exceed 10 pitches in an inning. Additionally, since most softball teams

only have one or two highly competitive pitchers, it is very common that a pitcher pitches two or three games in one day during a weekend tournament. Therefore, the question of how fatigue from pitching multiple games (back to back games) may affect pitching performance remained to be answered. This study hypothesized that with greater than 70 pitches in a single game and with a variety of pitches, the decrease of pitching performance of pitched ball velocity and spin rate may be observed as a sign of fatigue. Hence, the purpose of this study was to examine the influence of fatigue on softball pitching performance from pitching back to back games. The results would enable coaches, athletic trainers and health practitioners to establish guidelines for signs of pitching fatigue so that necessary pitching changes can be made during the game in order to prevent overuse injury, particularly for youth female pitchers. Additionally, a pitch count restriction for pitching multiple games could be established for the Amateur Softball Association, which could then be implemented at various levels of softball competition. Finally, a proper conditioning program could be prescribed to improve muscle strength for all pitchers to minimize the shoulder and elbow injuries.

METHODS: Three female college and one high school softball pitchers (mean age: 18.5 ± 2.6 years old; height: 1.7 ± 0.1 m; weight: 63.5 ± 15.1 kg) who were free of injury and participated in the study. The Institutional Research Board approval was obtained and written informed consent was obtained from the participants prior to the study. All participants wore black tight-fitting clothes with their softball cleats and arrived in an indoor softball training facility. Each participant warmed up prior to the study as they would in an actual game. Participants were fitted with joint reflective markers on the pitching side (throwing arm) of the body at the acromial-clavicular, lateral epicondyle of humerus, styloid process of radius, greater trochanter of femur, lateral epicondyle of femur, lateral malleolus and base of fifth metatarsal. Additional three markers were fitted on the opposite leg at the medial epicondyle of femur, medial malleolus and base of first metatarsal. The use of marker system on the participants was for a future study that will examine the effects of fatigue to pitching mechanics. Each participant threw five fastballs, five change-ups, and five curveballs toward a catcher. A pitch was considered successful and recorded when the catcher was able to catch the ball. If a ball was thrown and touched the ground or if the catcher was unable to catch the ball, the pitcher then threw another pitch for recording. After the participant threw a total of 15 successful pitches, the participant took a rest for 10 minutes and then threw another 15 pitches. The whole pitching process repeated for a total of seven times to mimic seven innings of a real game. After the participant completed seven innings of pitching, the participant rested for 20 minutes and then pitched for another seven innings to mimic back to back games. Each participant threw a total of 210 pitches during the two games. Data collection was approximately 1.5 hours for each participant. The order for the type of pitch in each inning and in each game were randomized to prevent order effect. One Casio (Model: EX-FH25) video camera was positioned to capture the sagittal view of the ball at 120 Hz and in conjunction with a 650W artificial spot light to assist in joint marker identification. Additionally, two RevFire^{TM} softballs were used to record angular ball velocity for the spin rate (rev/s). These special designed softballs have a gyroscope built inside of the ball with capability of measuring ball's spin rate. a doppler Rocket Radar^{TM} gun (Model: PR1000_BC) was used to measure the linear velocity of the pitched ball. All pitches in the 1st, 4th, and 7th innings of each game were recorded. A total of 90 pitches were recorded for each participant. The best three pitches with most consistency in each type of pitch in each inning were selected and used for data analysis. The Ariel Performance Analysis System computer software was used to determine the velocity of pitched ball to validate with radar gun. A one-way repeated measure ANOVA test was conducted at $\alpha = 0.05$ and followed by *t*-test with Bonferroni adjustment if a significant difference was found. All statistical analyses were conducted with SPSS (version 24) software.

RESULTS: The results of this study showed there was a significant difference in the fastball velocity after a game and half (after 4th inning of the 2nd game = approximately after 165 pitches). In the 1st inning of the first game, the mean fastball velocity was 25.4 ± 2.5 m/s, and it was significantly higher than the 4th inning of the second game with the mean fastball velocity

of 24.3 ± 2.7 m/s (p = 0.00) and also higher than the 7th inning of the second game with the mean fastball velocity of 24.4 ± 2.5 m/s (p = 0.00). There was no significant difference in the velocities of change-up and curveball, Table 1. Additionally, there was no significant difference found in the pitched ball's spin rate in all three different types of pitch, Table 2.

Table 1: Pitched ball velocity in three different types of pitch during multiple games.

Velocity (m/s)	Game 1 (1st Inning)	Game 1 (4th Inning)	Game 1 (7th Inning)	Game 2 (1st Inning)	Game 2 (4th Inning)	Game 2 (7th Inning)
Fastball	25.4 ± 2.5	25.1 ± 2.8	24.6 ± 3.2	24.3 ± 2.6	24.3 ± 2.7*	24.4 ± 2.5*
Change up	19.0 ± 1.3	18.4 ± 1.7	18.7 ± 1.0	17.1 ± 2.4	18.7 ± 1.1	19.0 ± 1.6
Curveball	24.6 ± 3.2	24.7 ± 3.0	24.3 ± 3.1	24.0 ± 3.2	23.8 ± 3.2	24.1 ± 2.6

**Statistical significant at p < .01*

Table 2: Pitched ball spin rate in three different types of pitch during multiple games.

Spin rate (rev/s)	Game 1 (1st Inning)	Game 1 (4th Inning)	Game 1 (7th Inning)	Game 2 (1st Inning)	Game 2 (4th Inning)	Game 2 (7th Inning)
Fastball	20.1 ± 2.1	19.8 ± 1.5	19.7 ± 1.4	19.2 ± 1.9	19.4 ± 1.4	18.9 ± 1.2
Change up	16.7 ± 6.8	16.7 ± 6.3	16.7 ± 7.4	16.9 ± 6.2	16.7 ± 7.0	15.3 ± 4.7
Curveball	18.8 ± 1.7	19.7 ± 2.1	19.4 ± 1.6	18.9 ± 1.3	18.8 ± 1.0	18.7 ± 0.7

**Statistical significant at p < .01*

DISCUSSION: Softball pitchers often pitch multiple games (2-4 games) in a weekend tournament. Currently, there is no regulation on how many pitches can a pitcher throw in order to protect them from overuse injury as in baseball. This study was the first softball pitching research that evaluated the effects of fatigue from pitching multiple games. In this study three most common types of pitch (fastball, change-up and curveball) were incorporated to mimic the real game situation. The results showed that the pitchers had a significant decrease in pitched ball velocity in the second game of 4th inning, which is approximately after 165 pitches. No significant differences were observed in the velocities of change-up and curveball. Since fastball requires pitchers to throw with maximal effort, pitchers showed signs of fatigue quicker than the other types of pitch. In previous research literature, softball pitchers threw 70 pitches of fastball and found no significant difference in pitched ball's velocity, but a trend of decline in ball's velocity was observed over seven innings (Postlmayr, Wu, & Ashely, 2012; Ashley, Wu & Postlmaryr, 2012). In this study softball pitchers threw a total of 210 pitches with mixed of fastball, change-up and curveball and was able to determine when did the pitcher experienced fatigue. Between previous literature and current study, the pitchers from this study showed similar pitching ball velocity as to the previous studies conducted by Barrentine et al. (1998), Werner et al. (2006), and Postlmayr et al. (2012) whom found pitchers to throw at a fastball velocity of 25 ± 2m/s, 27 ± 2m/s, and 26 ± 3 m/s respectively. This study also evaluated the effects of fatigue on the ball's spin rate in all three different pitches. It was hypothesized that the ball's spin rate would decrease as the result of fatigue, particular for the curveball. However, based on the results of this study, the effects of fatigue had no impact on the spin rate, and the pitchers were still able to generate same amount of spin on the ball even though the ball's velocity was decreased in the fastball pitch. Some limitations should be considered in this study. The sample size of the study was limited and with a greater sample size, the significance in ball's velocity may be observed in other types of pitch. Further, this study took place in an indoor facility, so the effects of fatigue in an outdoor environment during game situation will be greater. In this preliminary research study, the criteria for evaluating pitching performance outcome were pitched ball velocity and spin rate. However, since there was a significantly decrease in pitched ball velocity observed after a game and half, the effects of fatigue might have caused the change in pitching mechanics (e.g. decrease in the angular velocity of the arm, less elbow and wrist flexion or shorter stride length at ball release) given the repetitive action of the pitching arm. Future studies are warranted to examine the effects of fatigue on pitching mechanics to fully understand how fatigue may affect pitching technique/mechanics and performance. Moreover, in this study the rest period between

innings was 10 minutes and the rest period between games was 20 minutes as typically observed in a softball tournament. The authors recognize that resting period was a major factor in influencing fatigue recovery, and the longer resting period will minimize the effects of fatigue on pitching performance. Future studies are warranted to examine how different durations of rest period may affect pitching performance and mechanics.

CONCLUSION: This study suggests that the pitchers started to show signs of fatigue after a game and half (approximately 165 pitches), so softball coaches may take this into consideration and make necessary pitching change during the game to prevent overuse injury. The Amateur Softball Association (ASA) may use this information as in baseball to implement a pitch count to protect softball pitchers from overuse injury, particularly for youth pitchers during tournaments. Therefore, this study provides an important preliminary understanding on how fatigue could affect softball pitching performance, and future studies are warranted to conduct the study with a greater sample size and also to examine the effects of fatigue on pitching mechanics in multiple games with various durations of rest period.

REFERENCES

Ashley, J., Wu, T., & Postlmayr, C. (2012). The examination of softball pitching fatigability in lower extremities. *36th annual American Society of Biomechanics,* Gainesville, USA.

Corben, J. S., Cerrone, S. A., Soviero, J. E., Kwiecien, S. Y., Nicholas, S. J., & McHugh, M. P. (2015). Performance demands in softball pitching. *Journal of Sports Medicine, 43*(8)*,* 2035-2041.

Fleisig, G. S. (1994). *The biomechanics of baseball pitching.* Unpublished doctoral dissertation, University of Alabama, Birmingham.

Hill, J. L., Humphries, B., Weidner, T., & Newton, R. U. (2004). Female collegiate windmill pitchers: influence to injury incidence. *Journal of Strength Conditioning Resistance, 18*(3), 426-431.

Loosli, A. R., Requa, R. K., Garrick, J. G., & Hanley, E. (1992). Injuries to pitchers in women's collegiate fast-pitch softball. *American Journal of Sports Medicine, 20,* 35-37.

Lyman, S., Fleisig, G. S., Andrew, J. R., & Osinski, E. D. (2002). Effect of pitch type, pitch count, and pitching mechanics on risk of elbow and shoulder pain in youth baseball pitchers. *American Journal of Sports Medicine,* 30, 463-468.

Maffet, M. W., Jobe, F. W., Pink, M. M., Brault, J., & Mathiyakom, W. (1997). Shoulder muscle firing patterns during the windmill softball pitch. *American Journal of Sports Medicine, 25*(3)*,* 369-374.

Marshall, S. W, Hamstra-Wright, K. L, Dick, R, Grove, K. A, & Agel, J. (2007). Descriptive epidemiology of collegiate women's softball injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2003-2004. *Journal of Athletic Training, 42*(2), 286-294.

Postlmayr, C., Wu, T., & Ashley, J. (2012). Softball windmill pitch: necessity of a pitch count. *36th annual American Society of Biomechanics,* Gainesville, USA.

Smith, M., Davis, R., Brophy, R. H., Prather, H., Garbutt, J., & Wright, R. (2015). Prospective player-reported injuries in female youth fast-pitch softball players. *Sports Health, 7*(6), 497-503.

Werner S. L, Guido, J. A, McNeice, R. P, Richardson, J. L, Delude, N. A, & Stewart, G. W. (2005). Biomechanics of youth windmill softball pitching. *American Journal of Sports Medicine, 33*(4), 552-560

USA Softball (2017). Welcome to the USA softball youth program. Retrieved on January 24, 2017, http://www.teamusa.org/USA-Softball/Play-USA-Softball/Youth

ACKNOWLEDGEMENTS: The authors would like to thank all participants for their participation in the study and the support from Diamond Fastpitch, Inc. Additionally, the authors would like to acknowledge the Center for the Advancement of Research and Scholarship from Bridgewater State University for the research funding support.