Pitching Biomechanical Changes During Long Innings of a Division-I Collegiate Baseball Game

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Introduction: During a baseball game, maintaining pitching performance is essential for in-game success. Pitchers ideally maintain velocity levels and command in order to execute during the course of the game. Previous research has demonstrated that pitch velocity and biomechanics differed in the final inning of pitching compared to the first two innings. It remains unknown if velocity and pitching biomechanics change during a long inning of a game secondary to an atypical spike in workload within the inning. Therefore, the aim of this study was to determine if there are in-game biomechanical and pitch velocity changes during the course of a long inning. Our hypothesis was pitch velocity would decrease and baseline biomechanics would change.

Methods: Ninety-one (91) male NCAA Division-I pitchers were included this study. Data was collected during the 2022-2023 NCAA Season then filtered using the following inclusion criteria: 1) recorded at least one (1) appearance in a collegiate, regular season game and 2) pitched a minimum of greater than 15 pitches in an inning. If a pitcher logged more than one (1) inning with greater than 15 pitches, only the longest inning was included. Only fastball classified pitches were included in this analysis to remove pitch velocity variability. Ball tracking data was collected via TrackMan In-Stadium V3 (Vedbæk, Denmark). Videos of pitching events were collected during each game using an in-stadium, eight (8) camera Markerless Motion Capture System and processed using KinaTrax computer vision software (Boca Raton, FL) to derive joint-center tracking data (Pitching Model v6.3.9). Kinematics were calculated from C-Motion Visual 3D software (Boyds, MD). Ball tracking data and Markerless Motion Capture data were time-synchronized for each pitch to conduct analysis. Kinematics assessed were: Max Center of Mass Anterior/Posterior Velocity (CoM A/P Vel Max), Center of Mass Anterior/Posterior Velocity at Foot Contact (CoM A/P Vel FC; positive: toward home plate), Stride Length as a percentage of Body Height, Step Width (positive: lead leg closed with respect to the rear foot), Max Elbow Extension Velocity (MEEV), Max Shoulder Rotational Velocity (MSRV), Max Pelvis Rotational Velocity (MPRV), Max Trunk Rotational Velocity (MTRV), Lead Knee Angle Velocity Max, Lead Knee Flexion Velocity at Ball Release, and Trunk Flexion at Ball Release. A mixed-effects linear regression model ($\alpha<0.05$) was used to determine the effect of pitching greater than 15 pitches in an inning in comparison to the first 10 pitches thrown on various biomechanical variables related to pitch velocity.

Results: Pitch velocity showed a significant positive curvilinear trend in pitching velocity variability thrown after a count of 15 in comparison to the baseline first 10 pitches thrown in the inning (4.06 km/h (2.53 mph), = 0.010). Step Width (cm) demonstrated a significant negative curvilinear trend in pitches thrown after 15 (-6.74 cm/s, = 0.023). Table 1 highlights the results from both linear and quadratic regression models across pitch velocity and biomechanical kinematic variables of interest.

	CoM A/P Vel Max (cm/s)		CoM A/P Vel FC (cm/s)		Stride Length (%BH)		Step Width (cm)		MEEV (deg/sec)	
	Estimate	*p*	*Estimate*	*p*	*Estimate*	*p*	*Estimate*	*p*	*Estimate*	*p*
Pitch Count[1]	6.24	0.392	0.60	0.657	1.83	0.287	-4.15	0.189	-49.05	0.736
Pitch Count[2]	0.03	0.996	0.48	0.707	0.19	0.906	-6.74*	0.023	-205.27	0.136
	MSRV (deg/sec)		**MPRV (deg/sec)**		**MTRV (deg/sec)**		**Lead Knee Angle Vel Max (deg/sec)**		**Trunk Flexion BR (deg)**	
	Estimate	*p*	*Estimate*	*p*	*Estimate*	*p*	*Estimate*	*p*	*Estimate*	*p*
Pitch Count[1]	55.48	0.848	24.01	0.681	5.24	0.948	-50.65	0.361	1.60	0.511
Pitch Count[2]	-135.59	0.62	-3.44	0.95	45.76	0.548	-12.88	0.804	-4.38	0.056
	Pitch Velocity (km/h)		**Lead Knee Flexion Vel BR (deg/s)**							
	Estimate	*p*	*Estimate*	*p*						
Pitch Count[1]	1.21	0.477	37.70	0.513						
Pitch Count[2]	4.06*	0.010	-47.04	0.381						

*1Linear regression model; 2Quadratic regression model; *p < 0.05*

Table 1: Regression Results of Biomechanical Variables and Pitch Velocity

Discussion: During a long inning, pitch velocity demonstrated a significant curvilinear trend where velocity decreased after pitch 15 then trended towards an increase back to baseline at the end of the inning. This finding could be caused by multiple factors such as psychological internal motivation, coaches employing different in-game strategy, or the effect of a potential mound visit during a long inning. Further studies are recommended to evaluate these possible factors. Biomechanics did change with Step Width demonstrating a significant negative curvilinear trend meaning that players went from a closed to more open stance. Limitations of this study includes defining a long inning as pitching a minimum of greater than 15 pitches. It may be appropriate to increase the minimum pitch count to greater than 20.

Significance: The results from this study may have implications for coaches, clinicians, and athletic trainers who aim to understand the impact of long innings on health and performance. Understanding biomechanical changes during a long outing of an inning may affect performance and injury risk. Further studies based on these biomechanical changes are warranted.