COMPARISON BETWEEN SMARTPHONE MARKERLESS MOTION CAPTURE AND MARKER-BASED MOTION CAPTURE SYSTEMS DURING BASEBALL PITCHING

Pablo A. Ortiz [1], Mu Qiao [1], David J. Szymanski [1], and Ryan L. Crotin [1,2,3]
[1] Department of Kinesiology, Louisiana Tech University, Ruston, LA
[2] ArmCare.com, Indialantic, FL, [3] SPRINZ, AUT, Auckland, NZ

INTRODUCTION

Many factors contribute to improving a pitcher's fastball velocity, such as kinematics, kinetics, and relative timing of segmental interactions that lead to effective transfer of momentum to the baseball (10). Biomechanics are also an important factor to staying healthy throughout the course of a season as Birfer et al. (1) states that fatigue had a major impact on injuries and changes in kinematics. Slight changes in a pitcher's mechanics may result in higher or lower ball velocity, or even risk of injury as pitchers experience a change in loading that overwhelms muscles, ligaments, or tendons (7, 9).

Previous research has studied the kinematics of the baseball pitching delivery using three-dimensional (3D) motion capture cameras. 3D motion capture has become the gold standard to acquire a pitcher's kinematics during the pitching delivery (2, 3, 4, 5, 6, 10, 11). To collect 3D human movement, a laboratory setting is needed where baseball players are required to wear spandex, non-baseball spikes, and reflective markers on their body while performing the pitching delivery. Along with the unrealistic in-game setting, collecting 3D motion data is very time consuming in laboratory settings. The pitching delivery is an explosive, dynamic movement where reflective markers, at times, fly off the body during the delivery. New reflective markers are then needed to be replaced between pitches, making a bullpen session last longer than normal. Due to the elongated bullpen session, it is challenging to replicate the intensity applied in a game, making it hard to collect longitudinal data to study fatigue and its changes in kinematics.

With 3D motion capture systems being unrealistic to in-game settings and time consuming, coaches are unsure whether to spend their available time with their players collecting marker-based data. Markerless motion capture software would be ideal to help baseball coaches have a quicker way to access biomechanical data. It would also benefit to identify kinematic changes during a game and help make in-game decisions. Therefore, the purpose of this study was to compare the relationship between pitching kinematics (joint angles) from a 2D markerless motion capture application designed for a single camera smartphone to the gold standard 3D marker-based motion capture system during baseball pitching.

METHODS

Fourteen Division I collegiate baseball pitchers (age = 20.9 ± 1.7 yr, Ht = 184.5 ± 6.6 cm, BM = 89.1 ± 10.2 kg, LBM = 77.2 ± 7.1 kg, %BF = 13.2 ± 3.9%) volunteered for this study. Forty-eight reflective markers were attached bilaterally to the body (Figure 1 a & b). Markers were tracked by a 12-camera, 240Hz 3D motion capture system (model Miqus M3; Qualisys, Göteborg, Sweden).

For the markerless software, video was taken with an iPhone 13 Pro at 240Hz, 1080p resolution facing the frontal view of the pitching delivery. Video was uploaded to PitchAI's software (ProPlayAI, Ontario, Canada) where the program performed a 2D pose estimation of 19 joint center (Figure 2). PitchAI then transforms the 2D data into a 53 marker 3D joint center model (2).

Pitchers performed a standardized active, dynamic warm-up and then their own pitching warm-up routine before throwing off a custom-made pitching mound with 2 embedded force plates.

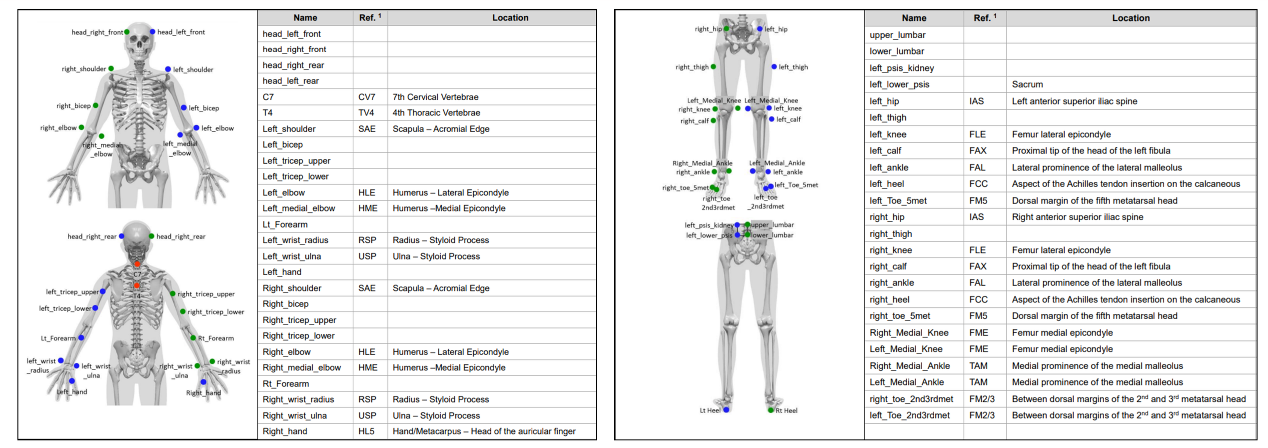

Figure 1 a & b. Anterior and posterior Qualisys marker locations.

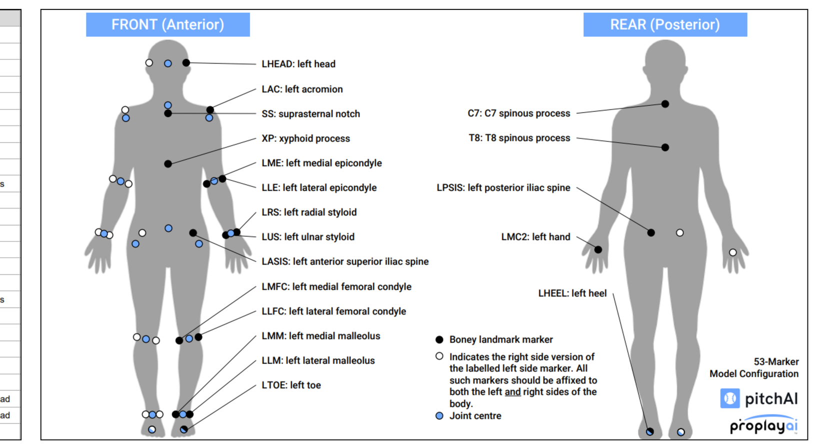

Figure 2. PitchAI 2D pose estimated markers.

METHODS

Pitchers were then instructed to go through a scripted bullpen where 36 (18 per inning) pitches were thrown. The first fastball recorded by both PitchAI and Qualisys was used for analyses.

Each pitch was adjusted and synchronized to begin from peak vertical knee position and end at ball release. Discrete-time points (Figure 3) were evaluated for 14 different joint kinematics using Pearson R (*r*), R-Squared (*r*²), and paired sample *t*-tests to compare PitchAI's and Qualisys data results. Interpretation of correlation coefficient is based on the suggestion of Safrit & Wood (8). Correlations were listed as high (± 0.800 - 1.00), moderately high (± 0.600 - 0.799), or moderate (± 0.533 - 0.599). Statistical significance was set at an alpha level of $p \leq 0.05$.

RESULTS

Table 1. R-squared (r^2) values for different joint angles at discrete-time points of the pitching delivery.

Joint Angle	Foot Plant	MER	Ball Release
Throwing Arm Elbow Flexion	0.54**	0.09	0.32***
Throwing Arm Shoulder Horizontal Abduction	0.01	0.06	0.00
Throwing Arm Shoulder Abduction	0.28	0.00	0.12
Throwing Arm Shoulder External Rotation	0.06	0.01	0.03
Glove Arm Elbow Flexion	0.00	0.00	0.06
Glove Arm Shoulder Horizontal Abduction	0.22	0.00	0.10
Glove Arm Shoulder Abduction	0.01	0.07	0.00
Glove Arm Shoulder External Rotation	0.02	0.01	0.01
Lead Knee Extension	0.31***	0.16	0.32***
Rear Knee Extension	0.10	0.37**	0.83*
Trunk Forward Tilt	0.00	0.06	0.14
Trunk Lateral Tilt	0.44**	0.01	0.00
Trunk Twist	0.03	0.09	0.14
Pelvis Twist	0.09	0.07	0.11

* = high correlation, ** = moderately high correlation, *** = moderate correlation.

Table 2. Paired sample *t*-test p-values for each joint angle at discrete-time points of the pitching delivery.

Joint Angle	Foot Plant	MER	Ball Release
Throwing Arm Elbow Flexion	0.001*	0.001*	0.01*
Throwing Arm Shoulder Horizontal Abduction	0.001*	0.001*	0.001*
Throwing Arm Shoulder Abduction	0.001*	0.12	0.001*
Throwing Arm Shoulder External Rotation	0.005*	0.001*	0.01*
Glove Arm Elbow Flexion	0.003*	0.03*	0.44
Glove Arm Shoulder Horizontal Abduction	0.001*	0.001*	0.001*
Glove Arm Shoulder Abduction	0.01*	0.02*	0.001*
Glove Arm Shoulder External Rotation	0.001*	0.001*	0.001*
Lead Knee Extension	0.04*	0.001*	0.02*
Rear Knee Extension	0.001*	0.001*	0.001*
Trunk Forward Tilt	0.001*	0.001*	0.001*
Trunk Lateral Tilt	0.60	0.001*	0.001*
Trunk Twist	0.001*	0.001*	0.001*
Pelvis Twist	0.19	0.001*	0.001*

* = significant difference.

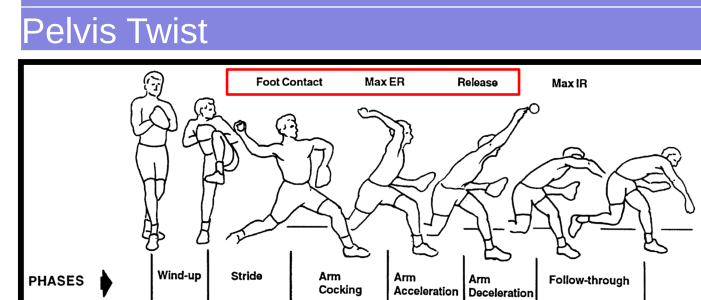

Figure 3. Discrete-time points (foot plant/contact, maximal external rotation, and ball release) during pitching delivery.

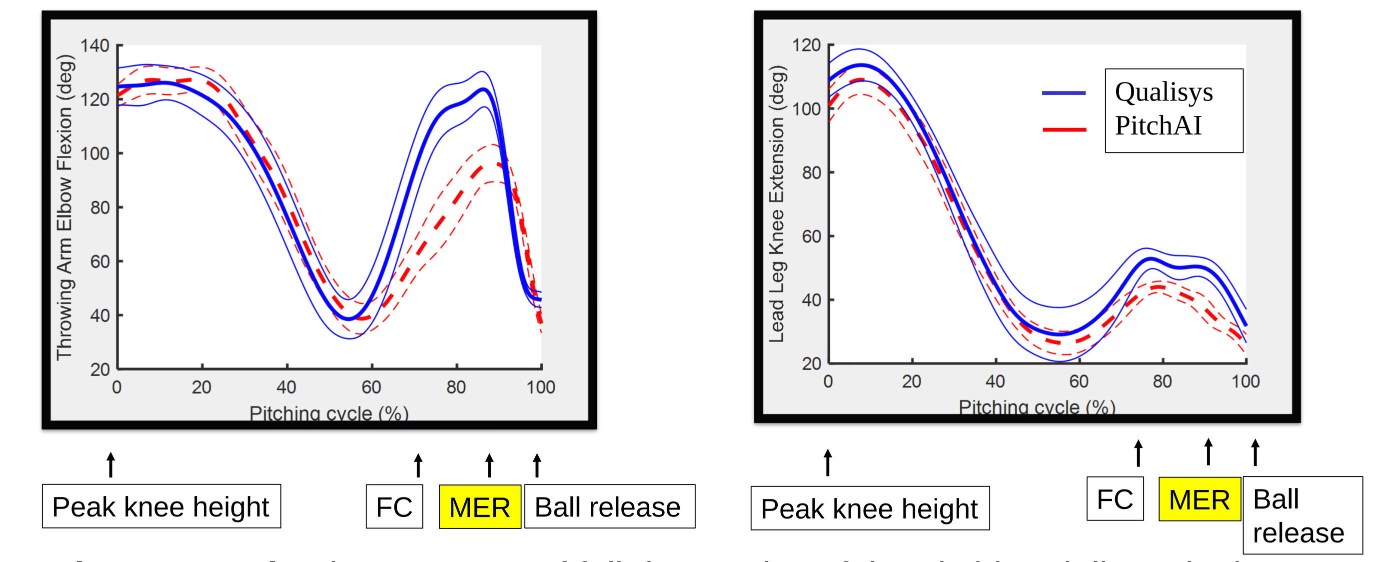

Figure 4 a & b. Linear-curves of full-time series of the pitching delivery in the throwing arm elbow flexion and lead knee extension.

CONCLUSIONS

Similar linear-curve trends were identified throughout the full-time series of the pitching delivery for both motion capture systems (Figure 4 a & b). Our results indicated there were some high to moderate correlations between systems (Table 1).

Although there were similar trends and some correlations, paired sample *t*-test identified significant differences between the two technologies (Table 2). These results were similar to those found by Fleisig et al. (6), where marker-based and markerless systems had similar 3D kinematic patterns, but significant differences existed between the systems. The results of the current study are in contrast to non-peer reviewed research by Dobos et al. (2), where strong correlations were identified between OptiTrack 3D motion capture and PitchAI markerless motion capture system.

PRACTICAL APPLICATIONS

PitchAI could be a useful technology to identify position-specific kinematic changes in an athlete's pitching motion, specifically for the lower extremities, lateral tilt of the trunk, and elbow flexion at foot contact and ball release. Significant differences exist between multi-camera 3D marker-based optimal segment tracking versus 2D markerless human modeling arising from single camera smartphone data captures. Although it could be a quicker way to access kinematic data during the pitching motion, coaches should be aware of the normative data provided for each motion capture software before making any changes in the athlete's kinematics. For instance, one system may identify that the athlete is not within the normative range of motion (ROM) for maximum external rotation and cannot be considered consistent between all systems. Coaches may want to increase the athlete's ROM in an attempt to gain greater throwing velocity. Ultimately, this approach may change the pitcher's ROM and expose the elbow to greater stress loads.

REFERENCES

1. Birfer, R, Sonne, MW, Holmes, MW. Manifestations of muscle fatigue in baseball pitchers: a systematic review. *Peer J*, *7*, e7390, 2019.
2. Dobos, T, Bench, R., McKinnon, C, et al. Validation of pitchAI markerless motion capture using marker-based 3D motion capture. *Sports Biomech* 10.1080/14763141.2022.2137425, 2022.
3. Escamilla, RF, Fleisig, GS, Barrentine, SW, et al. Kinematic comparisons of throwing different types of baseball pitches. *J Appl Biomech* 14(1): 1-23, 1998.
4. Fleisig, GS, Andrews, JR, Dillman, CJ, et al. Kinetics of baseball pitching with implications about injury mechanisms. *Amer J Sports Med* 23(2): 233-239, 1995.
5. Fleisig, GS, Barrentine, SW, Zheng, N, et al. Kinematic and kinetic comparison of baseball pitching among various levels of development. *J Biomech* 32(12): 1371-1375, 1999.
6. Fleisig, G, Slowik, JS, Wassom, D, et al. Comparison of marker and marker-less automated motion capture for baseball pitching biomechanics. *ISBS Proceedings Archive* 39(1): 13, 2021.
7. Grantham, WJ, Byram, IR, Meadows, MC, et al. The impact of fatigue on the kinematics of collegiate baseball pitchers. *Orthopaedic J Sports Med* 2(6): 2325967114537032, 2014.
8. Safrit, MJ, Wood, TM. Basic Statistics. In: *Introduction to Measurement in Physical Education and Exercise Science*. 3rd ed. St. Louis, MO: McGraw-Hill. pp. 43-84, 1995.
9. Seroyer, ST, Nho, SJ, Bach, BR, et al. The kinetic chain in overhand pitching: its potential role for performance enhancement and injury prevention. *Sports Health* 2(2): 135-146, 2010.
10. Stodden, DF, Fleisig, GS, McLean, SP, et al. Relationship of biomechanical factors to baseball pitching velocity: within pitcher variation. *J Appl Biomech* 21(1): 44-56, 2005.
11. Werner, SL, Fleisig, GS, Dillman, CJ, et al. Biomechanics of the elbow during baseball pitching. *J Orthopaedic Sports Phys Ther* 17(6): 274-278, 1993.