Author **Objectives**	**Design**	**Population**	**Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)**	**Performance factors associated with improved pitching performance**	**Results**
Bullock 2018 To investigate upper trunk rotation mobility and upper quarter dynamic stability, and their correlation to pitch velocity in NCAA Division I collegiate pitchers.	Cross-sectional design	N= 30 Age: 20.4 ± 1.5 years Division I college baseball pitchers.	Pitch velocity	Trunk rotation Upper Quarter Y-Balance Test (YBT-UQ)	No statistically significant correlations was found between trunk rotation mobility and pitching velocity; No statistically significant correlations was found between YBT-UQ and pitching velocity
Chen 2016 To compare the coordination patterns among youth baseball players of various ages and velocity levels by applying PCA and kinematic parameters.	Cross-sectional study	N=72 Little = elementary Junior = junior High Senior = senior High school Baseball players Age: **Little** (N=24): 11.0 ± 0.9 **High-velocity** (N=8): 11.0 ± 0.9 **Low-velocity** (N=8) 11.0 ± 0.5 **Junior** (N=24): 13.7 ± 1.0 **High-velocity** (N=8) 14.9 ± 0.3 **Low-velocity** (N=8)	Ball velocity	**Foot contact** Stride length SER/d (degree of shoulder external rotation) EF/d (degree of elbow flexion) LKF/d (degree of lead knee flexion) **Arm cocking phase** MPO/vel (maximal velocity of pelvic orientation) MUTO/vel (maximal velocity of upper torso orientation)	The older groups had higher pitching velocities than those of the younger group Differences between velocity levels : The high-velocity groups displayed a wider MSER angle and MUTO velocity during the arm-cocking phase, higher MSHA during the arm acceleration phase and wider SHA angles at the instant of ball release

Author **Objectives**	**Design**	**Population**	**Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)**	**Performance factors associated with improved pitching performance**	**Results**
		12.9 ± 0.3 **Senior** (N=24): 16.8 ± 0.8 **High-velocity** (N=8): 17.0 ± 0.8 **Low-velocity** (N=8) 17.0 ± 0.9		MEF/d (maximal degree of elbow flexion) MSHA MSER/d (maximal degree of shoulder external rotation) **Acceleration phase** MSER/vel MEF/vel (maximal velocity of elbow flexion) **Ball release** EF/d SHA/d (degree of shoulder horizontal adduction) FTT/d (degree of forward trunk tilt) LKF/d	The players with high velocity exhibited higher trunk and shoulder rotation velocity
Dun 2007 To investigate the differences of pitching kinematics between two different age groups of	Cross-sectional study	N=67 Age: 23.7 ± 3.3 Professional baseball pitchers	Ball velocity	Because they were significant, only the six following variables were	No association was found with ball velocity.

Author Objectives	Design	Population	Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)	Performance factors associated with improved pitching performance	Results
professional baseball pitchers. The hypothesis was that kinematic variables would be significantly affected by age.		Older group N=12 Younger group N=10		compared to ball velocity. **At lead foot contact** Stride length, upper trunk and pelvis orientation angles **During arm cocking phase** Maximum shoulder external rotation angle **At ball release** Lead knee angle and trunk forward tilt angle	
Elliott 1988 To investigate the role of ground reaction force (GRF) recorded from the pivot foot related to upper body movements in fastball (FB) and curveball (CB) pitching using both, i e. wind-up and set techniques.	Cross-sectional study	N=8 International baseball pitchers	Pitching velocity	Factors in the analyses were: type of delivery (wind-up, set), type of pitch (FB, CB), and time GRF (ground reaction force)	The slower pitchers appeared to begin their drive with the pivot limb earlier than the faster pitchers. The resultant forces decreased rapidly between the cocked position and stride-foot landing for the slower

Author Objectives	Design	Population	Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)	Performance factors associated with improved pitching performance	Results
					pitchers, while these forces did not significantly change between these positions for the faster pitchers. No difference was recorded in pitching velocity between the WU and S techniques. Higher resultant forces were recorded at the time the throwing arm was extended by the slow group, while the fast group recorded higher values at front-foot landing The ability to drive the body over a stabilized front leg was a characteristic of the fast pitchers.
Escamilla 2002 To quantify and compare kinematic, temporal, and kinetic	Cross-sectional study	N=19 American professional baseball pitchers	Ball velocity	**Kinematic variables** **Lead foot contact :**	The following variables are greater in the American pitchers and could explain the greater ball velocity.

Author Objectives	Design	Population	Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)	Performance factors associated with improved pitching performance	Results
characteristics of American and Korean professional pitchers in order to investigate differences in pitching mechanics, performance, and injury risks among two different cultures and populations of baseball pitchers.		(n=11) Age: 22.6±3.5 Korean professional baseball pitchers (n=8) 25.1+4.1		Stride length (% height) Shoulder abduction (°) Shoulder horizontal adduction (°) Shoulder external rotation (°) Knee flexion (°) ' Elbow flexion (°) **Arm-cocking phase** Maximum pelvis angular velocity (%) Maximum upper torso angular velocity (/s) Maximum elbow flexion (°) Maximum shoulder horizontal adduction (°) Maximum shoulder external rotation (°)	**Kinematic** **Lead foot contact :** Shoulder abduction, shoulder horizontal adduction and shoulder external rotation **Arm-cocking phase :** Maximum pelvis angular velocity Maximum shoulder external rotation **Instance of ball release :** Knee flexion Forward trunk tilt **Kinetic variables** **Arm-cocking phase :** Maximum shoulder internal rotation Torque maximum elbow varus torque **Arm acceleration phase** Maximum elbow flexion torque

Author **Objectives**	**Design**	**Population**	**Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)**	**Performance factors associated with improved pitching performance**	**Results**
				Arm acceleration phase Maximum elbow extension angular velocity (°/s) Maximum shoulder internal rotation angular velocity (°/s) Average shoulder abduction (°) **Instance of ball release** Knee flexion (°) Forward trunk tilt (°) Lateral trunk tilt (°) Elbow flexion (°) Shoulder horizontal adduction (°) Ball velocity (m/s)	**Arm deceleration phase** Maximum shoulder proximal force Maximum elbow proximal force

Author **Objectives**	**Design**	**Population**	**Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)**	**Performance factors associated with improved pitching performance**	**Results**
				Temporal variables Maximum Pelvis Angular Velocity (% of Pitch) Maximum Upper Torso Angular Velocity (% of Pitch) Maximum Elbow Flexion (% of Pitch) Maximum Shoulder External Rotation (% of Pitch) Maximum Elbow Extension Angular Velocity (% of Pitch) Maximum Shoulder Internal Rotation Angular Velocity (% of Pitch)	

Author **Objectives**	**Design**	**Population**	**Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)**	**Performance factors associated with improved pitching performance**	**Results**
				Kinetic variables **Arm-cocking phase** Maximum shoulder anterior force (N) Maximum shoulder horizontal adduction torque (N>m) Maximum shoulder internal rotation torque (NNm) Maximum elbow medial force (N) Maximum elbow varus torque(N-m) **Arm acceleration phase** Maximum elbow flexion torque (N-m)	

Author **Objectives**	**Design**	**Population**	**Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)**	**Performance factors associated with improved pitching performance**	**Results**
				Arm deceleration phase Maximum shoulder proximal force (N) Maximum elbow proximal force (N) Maximum shoulder adduction torque (N-m) Maximum shoulder posterior force (N) Maximum shoulder horizontal abduction torque (N-m)	
Freeston 2015 To describe any relationship between shoulder proprioception acuity and throwing speed or accuracy.	Descriptive, cross-sectional laboratory study	N=22 Age: 19.6 ± 2.6 Adolescent male athletes	Maximal throwing speed Accuracy	Proprioception	No significant relationship was found between any of the variables
Howenstein 2019	Cross-sectional study	N=24	Pitch velocity Joint load efficiency	EF (energy flow) into pelvis EF into trunk	All EF variables were positively correlated to pitch velocity

Author **Objectives**	**Design**	**Population**	**Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)**	**Performance factors associated with improved pitching performance**	**Results**
To investigate the transfer of energy through the kinetic chain by youth baseball pitchers during the pitching motion and 2) to provide insight into how the total magnitude of energy flow and its linear and rotational components relate to both velocity and joint torque per unit increment of pitch velocity (joint load efficiency).		Age: 11.1 ± 1.3 (range between 9 and 13) Youth baseball pitchers (at least one year of experience)		EF into arm (shoulder) EF into upper arm EF into forearm EF into hand	
Jinji 2011 To investigate the factors that a pitcher exerts to determine the direction of the spin axis of a baseball.		N=19 Age 20.1+3.4 Male baseball pitchers Professional pitchers (n=4) Intercollegiate league (n=7) High school (n=8)	Direction of the spin axis	Parameters representing the angles of the hand direction At MER (maximum external rotation), WVmax (instant of maximum velocity of the wrist), MPVmax (instant of maximum velocity of the	The orientation of the hand just before ball release was a significant factor in determining the direction of the ball spin axis. To increase the lift force, the palm needs to face home plate.

Author Objectives	Design	Population	Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)	Performance factors associated with improved pitching performance	Results
				Metacarpal joint center) and BRL (instant of ball release) Right/left rotation Right/left sideways Backward/forwar d tilt	
Kawamura 2017 To comprehensively evaluate pitching accuracy using three different quantitative measures applied to two groups of pitchers: professional pitchers and high school pitchers. by evaluating pitching accuracy quantitatively, the hypothesis that professional pitchers	Cross-sectional study	N=13 Professional baseball pitchers (n=5) Age: 26.2 ± 2.7 High school baseball pitchers (n=8) Age: 17.0 ± 0.0	Pitching accuracy Pitch location accuracy (95% confidence ellipse) Error evaluations（AE, CE） PL trajectory (PLT)	Level of play	Ellipses of professional pitchers tend to be narrower than those of high school pitchers. Professional pitchers had better control in the horizontal direction of pitching than high school pitchers. The PLTs in professionals were significantly smaller to those in high school pitchers in 30 pitches (20 fastball and 10 breaking ball pitches).
Keller 2015 To evaluate changes in throwing shoulder range of motion in	Cross-sectional study	N=22 Age: 16.9 (range, 15-19 years). High school pitchers	Pitching velocity	Glenohumeral internal rotational deficit Increased glenohumeral	No significant correlation was found between pitch velocity and any of the variables.

Author **Objectives**	**Design**	**Population**	**Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)**	**Performance factors associated with improved pitching performance**	**Results**
high school pitchers and determine whether these changes directly correlated with differences in maximum pitch velocity.				External rotation Age Height Weight Body mass index Dominant hand	
Lehman 2013 To determine which lower-extremity field tests correlate with throwing velocity to provide coaches and athletes with more direction in creating training programs that are highly associated with increases in throwing velocity.	Cross-sectional study	N=42 Age: 19.8 ± 1.2 College baseball players	Throwing velocity	**Anthropometrics** Height Weight (BW) **Lower-body field test →** **Medicine ball throws** MB scoop toss and MB squat throw **Vertical jumps** bilateral and unilateral **Horizontal Jumps** The horizontal broad jump, hop and stop **Lateral to Medial Jump (LMJR)**	**Contributing role in throwing velocity:** **Stretch position: Right-Hand Throw** BW LMJR **Shuffle position: Right-Hand Throw** LMJR MB scoop **Stretch position: Left-Hand Throw** LMJL **Shuffle position: Left-Hand Throw** BW LMJR LMJL

Author Objectives	Design	Population	Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)	Performance factors associated with improved pitching performance	Results
				Bilateral Triple Jump **Speed Tests** 10-yd sprint 60-yd sprint 10-yd single-leg hop test	
Makhni 2018 To assess the precision of a new wearable device in detecting medial elbow torque during the pitching motion in competitive baseball pitchers and to determine the differences in torque across pitch types and thrower demographic characteristics.	Comparative study	N=37 Age: 18.2 ± 0.2 Male baseball pitchers High school and collegiate	Ball velocity Variability	Pitch type **Demographic variables** Age Height Weight Body mass index, Total arm length, Upper arm length, Forearm length, Elbow circumference	Fastball produces the highest ball velocity Player height is the best predictor for the increase in variability (shorter pitchers have higher variability within any pitch type) Ball velocity was best predicted by high elbow torque, elevated shoulder rotation, and heavier weight.
Matsuo 2001 To investigate differences in kinematics and temporal parameters during baseball pitching between high	Cross-sectional study	N=127 High velocity group N=29 (21 professional, 8 college)	Ball velocity	**Kinematics** Stride length Maximum pelvis linear velocity	For the high velocity group : Maximum lead knee flexion angular velocity was smaller

Author **Objectives**	**Design**	**Population**	**Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)**	**Performance factors associated with improved pitching performance**	**Results**
and low velocity groups.		Low velocity group N=23 (college)		Maximum pelvis rotation angular velocity Maximum shoulder horizontal adduction angular velocity Maximum lead knee flexion angular velocity Maximum upper torso rotation angular velocity Maximum shoulder external rotation Maximum forward trunk tilt angular velocity Maximum elbow extension angular velocity Maximum shoulder internal rotation angular velocity Lead knee extension angular	Maximum shoulder external rotation was greater Lead knee extension angular velocity at the instant of ball release was greater Forward trunk tilt at the instant of ball release was greater Maximum elbow extension angular velocity occurred earlier Maximum shoulder internal rotation angular velocity occurred earlier

Author **Objectives**	**Design**	**Population**	**Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)**	**Performance factors associated with improved pitching performance**	**Results**
				velocity at the instant of ball Release Forward trunk tilt **at the instant of ball release** **Temporal** Maximum pelvis linear velocity Maximum pelvis rotation angular velocity Maximum shoulder horizontal adduction angular velocity Maximum lead knee flexion angular velocity Maximum upper torso rotation angular velocity Maximum shoulder external rotation Maximum elbow extension angular velocity	

Author Objectives	Design	Population	Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)	Performance factors associated with improved pitching performance	Results
				Maximum forward trunk till angular velocity Maximum shoulder internal rotation angular velocity	
Murata 2001 To verify the hypothesis that a pitcher with less movement (displacement) of the shoulder of the non-throwing arm can attain higher ball velocities.	Cross-sectional study	N=9 Age: 18 to 25 Baseball pitchers from a business corporation (n=6) and from high school (n=3) Skilled group: N=4 (2 high school, 2 corporate) Unskilled group: N=5 (1 high school, 4 corporate)	Ball velocity	Shoulder-joint movement (SJM) index of the non-throwing arm	The lower the SJM are, the faster is the ball velocity.
Nakata 2013 To clarify how anthropometric and physical fitness characteristics and speed are related to actual performance of young	Cross-sectional study	N=164 Age: 6.4–15.7 years Male baseball pitchers Youngest N= 51	Pitching velocity	Months of age Months of baseball experience Height Weight Standing long jump	**All participants together :** Age, BMI, standing long jump, 10-m sprint, and grip strength were found to be significant

Author Objectives	Design	Population	Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)	Performance factors associated with improved pitching performance	Results
baseball players attending elementary and junior high schools.		Middle N=56 Oldest N=57		Side steps sit-ups 10-m sprint Trunk flexion Back strength Grip strengths of left and right hands	predictors of pitched ball kinetic energy **Youngest group**: Side steps, 10-m sprint, trunk flexion, and right grip strength were significant predictors of pitched ball kinetic energy **Middle group :** Sit-ups and 10-m sprint were significant predictors of pitched ball kinetic energy **Oldest group :** The 10-m sprint was a significant predictor of pitched ball kinetic Energy
Oyama 2018 To investigate the correlation	Cross-sectional study design	N=52 Age : 15.4 ± 1.2	Ball speed	Peak vertical GRF (N/BW) Peak anterior GRF (N/BW)	Ball speed was significantly weakly correlated to peak resultant force, and to

Author **Objectives**	**Design**	**Population**	**Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)**	**Performance factors associated with improved pitching performance**	**Results**
between GRF characteristics during push off and ball speed in high school baseball pitchers.		High school baseball pitchers		Peak resultant GRF (N/BW) Vertical force at time of peak anterior force (N/BW) Resultant force at time of peak anterior force (N/BW) Impulse of the anterior GRF (Ns/BW) GRF : ground reaction force BW : body weight N : newton Newton-second	vertical and resultant forces at the time of peak anterior force
Oyama 2013 To investigate the effects of excessive contralateral trunk tilt, a common technique identifiable by video observation, on pitching biomechanics and performance in high	Descriptive laboratory study	N= 72 Age: High school pitchers	Ball speed	**Kinetic variables** Peak elbow proximal force Peak elbow varus moment Peak shoulder proximal force Peak shoulder internal rotation moment	The pitchers who demonstrated excessive contralateral trunk lean had a higher ball speed For the pitchers with excessive contralateral trunk lean, shoulder proximal

Author **Objectives**	**Design**	**Population**	**Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)**	**Performance factors associated with improved pitching performance**	**Results**
school baseball pitchers.				**Kinematic variables** **At Stride foot contact, maximal shoulder external rotation and ball release:** Upper torso rotation angle Upper torso lateral flexion angle Upper torso forward flexion angle **At maximal shoulder external rotation:** Shoulder external rotation angle Shoulder horizontal abduction angle Shoulder elevation angle Elbow extension angle **At ball release :**	force and elbow proximal were significantly correlated with ball speed

Author **Objectives**	**Design**	**Population**	**Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)**	**Performance factors associated with improved pitching performance**	**Results**
				Shoulder horizontal abduction angle Shoulder elevation angle Elbow extension angle	
Oyama 2014 The aim of this study was to investigate the effects of trunk rotation sequence on ball speed and on upper extremity biomechanics that are linked to injuries in high school baseball pitchers.	Descriptive laboratory study.	N=55 Age: 15.5 ± 1.2 High school pitchers **Group with proper trunk rotation sequence:** N= 22 Age: 15.7 ± 1.3 **Group with improper trunk rotation sequence:** N=33 Age: 15.5 ± 1.1	Ball speed	Trunk rotation sequence (proper vs improper)	No significant difference was found between the 2 groups.
Post 2015	Cross-sectional study	N=67 Age: 19.5 ± 1.2	Ball velocity	Peak elbow-valgus torque	A significant weak correlation was found between ball velocity

Author **Objectives**	**Design**	**Population**	**Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)**	**Performance factors associated with improved pitching performance**	**Results**
To examine the correlation of peak ball velocity with elbow-valgus torque, shoulder external-rotation torque, and shoulder-distraction force in a group of collegiate baseball pitchers.		NCAA Division I collegiate baseball pitchers		Shoulder-distraction force Shoulder external-rotation torque	and shoulder-distraction force.
Ramsey 2018 To examine the effect of stride length on vertical and antero–posterior GRF patterns during the propulsive and braking phases of the overhand throwing delivery.	Randomized crossover design	N=19 Age: 18.6 ± 1.7 Healthy and skilled competitive pitchers from collegiate (n=15) and high school (n=4) seasonal travel programs	Ball velocity	**Stride length :** Normal 25% less 25% more	Mean and peak ball velocities were no different between stride length conditions
Roach 2014	Cross-sectional study	N=21 Age: 19–23 Male subjects	Ball speed Accuracy?	Torso rotation Shoulder internal rotation Elbow extension Wrist flexion	When the torso restriction brace was applied, maximum ball speed dropped moderately Clavicle (sham) : maximum ball speed (-3 ± 5%

Author Objectives	Design	Population	Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)	Performance factors associated with improved pitching performance	Results
					restriction : maximum ball speed dropped by a further 3 ± 6% Shoulder (sham) : there were also slight reductions in mean maximum ball speed - 3±5%, Restriction: The restricted trials caused an 8±6% reduction in maximum ball speed relative to the sham trials
Robb 2010 To describe side-to-side differences in passive ROM (PROM) of the hips among professional baseball pitchers. The secondary analysis was to determine correlations between their hip PROM and their	Cross-sectional study	N=19 Age: Male professional baseball pitchers	Ball velocity	**Hip range of motion (ROM)** External rotation Internal rotation Total arc of rotation ADD (adduction) ABD (abduction) Total arc of ADD + ABD	Total arc of rotation of the nondominant hip is significantly correlated to ball velocity.

Author **Objectives**	**Design**	**Population**	**Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)**	**Performance factors associated with improved pitching performance**	**Results**
pitching biomechanics and ball velocity.					
Sgroi 2015 To determine the demographic and biomechanical factors that predict throwing velocity. We hypothesized that pitchers with higher velocity would have shared demographic and kinematic characteristics.	single-episode cross-sectional study	N=420 Age: 14.7 ± 2.6 Youth and adolescent overhand baseball pitchers	Pitch velocity	**Demographic variables** Age Height Weight BMI **Physical examination** ER-Dom IR-Dom Arc-Dom GIRD GERE **Wind-up kinematics at front foot contact** Max. knee height Stride length Elbow flexion Knee flexion Shoulder abduction	The most important correlates with pitch velocity were age, height, separation of the hips and shoulders, and stride length.

Author **Objectives**	**Design**	**Population**	**Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)**	**Performance factors associated with improved pitching performance**	**Results**
				Foot angle **Kinematics at maximum shoulder ER** Max. shoulder ER Max. shoulder abduction Lateral trunk tilt **Kinematics at ball release** Elbow flexion Forward trunk tilt Knee flexion Shoulder abduction Lead hip flexion Lateral trunk tilt **Observed mechanics** Leads with hips Hand on top of ball Arm in throwing position at front foot contact	

Author **Objectives**	**Design**	**Population**	**Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)**	**Performance factors associated with improved pitching performance**	**Results**
				Closed shoulders at hand separation Foot closed Hip and shoulder separation Fielding position at follow-through	
Solomito 2018 To determine the association between sagittal plane trunk motion and elbow varus moment and ball velocity in collegiate baseball pitchers.	Descriptive laboratory study	N=99 Age: 19.9 ± 1.4 Division I and Division III NCAA pitchers	Ball velocity	Sagittal plane trunk motion	There are statistically significant associations between trunk forward flexion at ball release and both maximum elbow varus and ball velocity For every 10 sec of forward trunk tilt beyond the median forward trunk flexion (28 °), there was a 2.9-N increase in elbow varus moment as well as a 0.7-m/s (1.5-mph) increase in ball velocity (a 2% increase in ball velocity indicating a substantial increase in the joint moment with a limited increase in ball velocity.

Author Objectives	Design	Population	Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)	Performance factors associated with improved pitching performance	Results
Solomito 2015 To determine the association between contralateral trunk lean and ball velocity and the moments about the elbow and glenohumeral joint.	Descriptive laboratory study.	N=99 Age: 19.9 ± 1.4 NCAA Division I and Division III college pitchers	Ball velocity	Contralateral trunk lean	Statistically significant associations were found between contralateral trunk lean and increased ball velocity: for every 10º increase in contralateral lean, ball velocity increased 0.5 m/s.
Stodden 2005 To examine the relationship between fastball velocity and variations in kinematic, kinetic, and temporal parameters within individual pitchers.	Cross-sectional study	N=19 Age: 20.9 ± 2.1 Elite baseball pitchers Professional (n=7) College (n=9) High school (n=3)	Ball velocity	**Kinematic parameters** Shoulder abduction at **SFC** Shoulder horizontal adduction at **SFC** External rotation at **SFC** Stride leg knee angle at **SFC** Elbow angle at **SFC** Maximum shoulder horizontal adduction Maximum external rotation	The following variables are associated with ball velocity : **Kinematic parameters :** Shoulder horizontal adduction at SFC Average abduction during acceleration Trunk tilt forward at release **Kinetic parameters :** Shoulder proximal force (%BW) Elbow proximal force (%BW)

Author **Objectives**	**Design**	**Population**	**Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)**	**Performance factors associated with improved pitching performance**	**Results**
				Average abduction **during acceleration** Trunk tilt forward **at release** Trunk tilt sideways **at release** Elbow angle **at release** Shoulder horizontal adduction **at release** **Kinetic parameters** Shoulder anterior force (%BW) Shoulder proximal force (%BW) Elbow proximal force (%BW) Shoulder horizontal adduction torque (%BWxH) Shoulder internal rotation torque (%BWxH)	Elbow flexion torque (%BW3H) **Temporal parameters:** Maximum horizontal adduction (% pitch) Maximum internal rotation angular velocity (% pitch)

Author **Objectives**	**Design**	**Population**	**Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)**	**Performance factors associated with improved pitching performance**	**Results**
				Elbow varus torque (%BWxH) Elbow flexion torque (%BWxH)	
Stodden 2001 To investigate the relationship between 12 pelvis and upper torso kinematic variables and pitched ball velocity.	Cross-sectional study	N=19 Age: 20.9 ± 2.1 Elite baseball pitchers Professional (n=7) College (n=9) High school (n=3)	Ball velocity	**Instant of maximum knee height** Upper torso orientation Pelvis orientation **Instant of front foot contact** Upper torso orientation Pelvis orientation **Arm cocking phase** Upper torso velocity Pelvis velocity **Instant of maximum shoulder external rotation** Upper torso orientation Pelvis orientation **Arm acceleration phase** Upper torso velocity	The following variables increase as the ball velocity increases : Pelvis orientation angle and upper torso orientation angle at the instant of maximal external rotation of the throwing shoulder (MER) Pelvis orientation angle at ball release (Rel) Average pelvis velocity from front foot contact (FFC) to MER Average upper torso velocity from MER to Rel

Author **Objectives**	**Design**	**Population**	**Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)**	**Performance factors associated with improved pitching performance**	**Results**
				Pelvis velocity **Instant of ball release** Upper torso orientation Pelvis orientation	
Tocci 2017 To investigate the effect of pitch mechanics on peak elbow varus torque in healthy youth pitchers.	Cross-sectional study	N=18 Age: 15.46 ± 1.6 Male youth pitchers	Peak elbow varus torque	**Ball velocity** Stride length Pelvic tilt Release point distance	During fastballs, pitch velocity was significantly associated with peak elbow varus torque.
Urbin 2013 To identify where in the throwing motion the timing of successive peak angular velocities tends to vary and how these variations affect ball speed and the magnitudes of upper extremity kinetics.	Descriptive laboratory study	N=16 Age: Collegiate pitchers (n=8) Professional pitchers (n=8)	Ball speed	**Temporal Parameters** Stride-foot contact Peak pelvis angular velocity Peak upper torso angular velocity Peak elbow extension velocity Ball release	Decreased ball speed correlated with increased time from stride-foot contact to peak pelvis angular velocity and increased time from peak upper torso angular velocity to peak elbow extension angular velocity.
Van Trigt 2018 To determine whether stride length and knee angle of	Cross-sectional study	N=52 Age: 15.2 ± 1.7 Baseball pitchers	Ball speed	Relative stride length and knee angles at FC, MER, and BR	stride length and knee angle at FC are not associated with ball speed

Author **Objectives**	**Design**	**Population**	**Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)**	**Performance factors associated with improved pitching performance**	**Results**
the leading leg at foot contact, at the instant of maximal external rotation of the shoulder, and at ball release are associated with ball speed in elite youth baseball pitchers.		range 10.4–18.5).			knee extension at MER and BR appeared to be significantly and positively associated with higher ball speeds. The increase in ball speed, which is associated with a more extended knee at MER and BR, is relatively small.
Wang 1995 To examine the relations of pitching performance or ball velocity at release to maximum external rotation of the shoulder and time of the acceleration phase and to identify the kinematic characteristics of the throwing-arm patterns during the acceleration phase.		N=3 Age: 19 to 21 Male baseball pitchers College (n=2) High school (n=1)	Ball velocity	Maximum external rotation of the shoulder Time of the acceleration phase	Increasing maximum external rotation of the shoulder at the very beginning of the acceleration phase would help generate a greater ball velocity. Slowing down the wrist action just before ball-release may be a key technique to the increase of pitching ball velocity. Time of acceleration phase?
Werner 2008 To evaluate the	Cross sectional study	N=54 Age: 20 ± 2 years	Ball velocity	Anthropometric measures	All the following variables are associated to ball velocity :

Author Objectives	Design	Population	Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)	Performance factors associated with improved pitching performance	Results
relationships between pitching mechanics and ball speed in a group of collegiate baseball pitchers and to compare the results with previous studies.		College baseball players (NCAA and NAIA)		Kinematic et kinetic parameters	Body weight Time, SFC to MER Knee flexion at SFC Elbow flexion at SFC Time, head behind hips Max shoulder angular velocity Max shoulder ER Max elbow extension angular velocity Knee flexion at REL Trunk tilt at REL
Whiteside 2016 To quantify how ball flight kinematics (I.e., ball speed and movement), release location, and variations therein relate to pitching success in Major League Baseball (MLB).	Cross-sectional	N= 190 Starting MLB pitchers	Fielding independent pitching (FIP)	Ball flight kinematics (ball speed, ball movement, variation in speed and movement) Release location	Pitch speed, release location variability, variation in pitch speed, and horizontal release location were significant predictors of FIP and, collectively, accounted for 24% of the variance in FIP
Whiteside 2016 To quantify ball flight kinematics (ball speed, spin rate, spin axis orientation, seam orientation) and	Cross-sectional	N=9 Age: 20.69 ± 1.52 NCAA Division I Pitchers	Fielding independent pitching (FIP) → home runs, walks, hit by pitches, and strikes.	Ball kinematics (ball speed, spin rate, spin axis orientation, seam orientation)	None of the kinematic ball flight variables, nor the release variability, were significantly correlated to FIP.

Author Objectives	Design	Population	Performance indicators (Ball speed/velocity, accuracy, spin rate, games stats)	Performance factors associated with improved pitching performance	Results
release location variability in the four most common pitch types in baseball and relate them to in-season pitching performance.				Release location variability across pitches	