Kinetic Comparison Among the Fastball, Curveball, Change-up, and Slider in Collegiate Baseball Pitchers

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Background: Controversy exists about whether breaking pitches are more stressful than are fastballs. Previous biomechanical studies compared kinematics but not kinetics.

Hypothesis: Elbow and shoulder forces and torques are statistically different among the fastball, curveball, change-up, and slider.

Study Design: Descriptive laboratory study.

Methods: Twenty-one healthy collegiate pitchers were studied with a high-speed automated digitizing system. All subjects threw fastballs (n = 21), most threw curveballs (n = 20) and change-ups (n = 19), and a few threw sliders (n = 6). Wrist, elbow, and shoulder kinetics were calculated using inverse dynamics. Nine kinetic and 26 kinematic parameters were compared among the different pitch types using repeated-measures analysis of variance.

Results: At the shoulder, internal rotation torque, horizontal adduction torque, abduction torque, and proximal force were significantly less in the change-up than in the other 3 pitches. Shoulder horizontal adduction torque was greater in the fastball than in the curveball and slider. Shoulder proximal force was greater in the slider than in the curveball. Elbow proximal force was less in the change-up than in the other 3 pitches. Elbow varus torque was greater in the fastball and curveball than in the change-up. Elbow flexion torque was greater in the curveball than in the change-up. The curveball and change-up demonstrated kinematic differences from the fastball, consistent with previous studies.

Conclusion: There were significant kinematic differences between the fastball and curveball but few kinetic differences. The change-up had lower joint kinetics, lower angular velocities, and different body positions than the other 3 pitch types had. Results for the slider were inconclusive because of small sample size.

Clinical Relevance: Because the resultant joint loads were similar between the fastball and curveball, this study did not indicate that either pitch was more stressful or potentially dangerous for a collegiate pitcher. The low kinetics in the change-up implies that it is the safest.

Keywords: elbow; shoulder; wrist; force; torque; kinematics; pitching; biomechanics

In 1989, the 26 Major League Baseball teams had a total of 118 pitching disabilities for a total of 8319 days.[3] In 1999, there were 30 Major League Baseball teams, and these teams had 182 pitching disabilities for 13 129 disabled days.[3] Thus, whereas there was a 15% increase in the number of teams and players in Major League Baseball from 1989 to 1999, there was a 54% increase in the number of pitchers disabled and a 58% increase in the number of days they missed. In our experience, the increased numbers of elbow and shoulder injuries are even worse at the high school and college levels. Consider our senior author (J.R.A.), who operated on elbows of 184 baseball pitchers (91 professional, 71 collegiate, 21 high school, and 1 recreational) between 1995 and 1999 and elbows of 624 baseball pitchers (196 professional, 302 collegiate, 124 high school, and 2 recreational) between 2000 and 2004. Comparing these consecutive 5-year periods, there were approximately twice as many elbow surgeries for professional pitchers, 4 times as many for collegiate pitchers, and 6 times as many for high school pitchers. It is impossible to separate what part of these dramatically increased numbers is owing to an epidemic of increased number of injuries versus other factors such as improved ability to

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No potential conflict of interest declared.

The American Journal of Sports Medicine, Vol. 34, No. 3
DOI: 10.1177/0363546505280431

identify injuries and improved recognition of our senior author's expertise in this field. Regardless, baseball pitching injuries are clearly a serious problem at all levels.

There have been numerous advances in surgical and nonsurgical treatments of shoulder and elbow injuries in baseball pitchers. However, the best treatment the medical community can give baseball pitchers is education about injury prevention. Pitch counts, pitch types, pitch mechanics, physical conditioning, periodization, nutrition, and supplements are some of the factors often believed to be related to the risk of overuse injury in pitchers.[9,14] There continues to be much controversy about whether throwing curveballs or other types of breaking pitches are more stressful and dangerous for the shoulder and elbow than are fastballs.

In 1986, Elliott and Grove[7] published the first biomechanical study comparing fastball and curveball kinematics. Based on 6 Australian national pitchers tested with a 2-camera manual digitizing system, they found that fastball and curveball mechanics were similar in general, but stride length, forearm action, and wrist action were different. Sakurai et al[18] compared fastball and curveball kinematics in 6 Japanese collegiate pitchers. They found no differences in shoulder and elbow kinematics but significant differences in forearm and wrist actions. In 1998, the American Sports Medicine Institute published 2 studies looking at kinematic differences among fastball, curveball, change-up, and slider pitches. Compared with the fastball and change-up, the curveball exhibited a shorter stride, more forearm supination, and less wrist extension.[1,8] Of those 3 pitches, the curveball had the slowest trunk rotations, and the change-up had the slowest arm rotations.[8] In general, slider kinematics has been shown to be similar to fastball kinematics.[8]

Sisto et al[19] compared elbow muscle activity during fastball and curveball pitches. They found slight but statistically insignificant increases in extensor carpi radialis brevis activity and extensor carpi radialis longus activity in the curveball compared to the fastball. The authors stated that these slight increases most likely reflect different wrist and forearm positioning between the 2 types of pitches. In a subsequent study, Glousman et al[13] compared elbow muscle activity between healthy pitchers and injured pitchers with medial collateral ligament (ulnar collateral ligament) insufficiency. They found some significant differences between healthy and injured pitchers for both the fastball and curveball.

Thus, the literature and current recommendations imply that breaking pitches might be stressful throws that increase the risk of arm pain and injury potential. Previous studies have shown kinematic differences between pitch types, but shoulder and elbow kinetics have not been reported. The purpose of this study was to quantify and compare shoulder and elbow kinetics among fastball, curveball, change-up, and slider pitches. It is hypothesized that there are kinetic differences among the pitch types, which may support the notion that certain types of pitches are more stressful and dangerous to the throwing shoulder and elbow. Kinematic and temporal parameters will also be compared among the 4 pitch types.

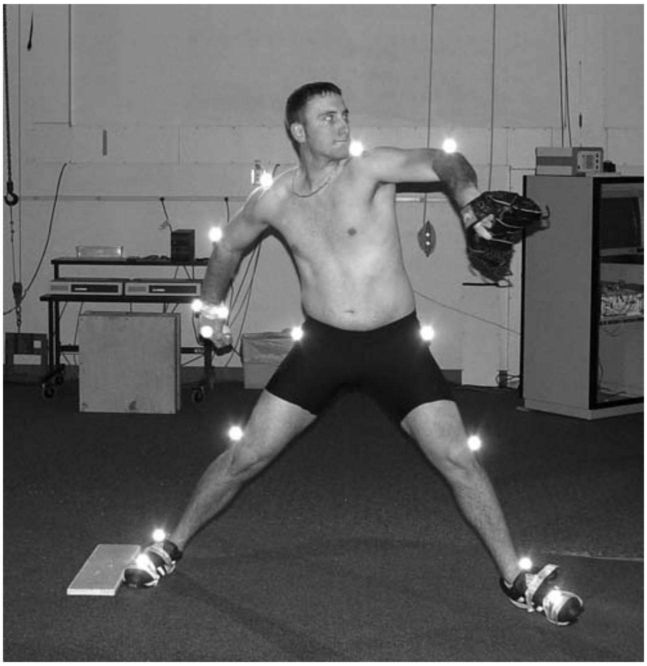

Figure 1. Reflective marker setup.

MATERIALS AND METHODS

Twenty-one healthy male collegiate baseball pitchers (age, 20 ± 1 years; mass, 85.3 ± 8.8 kg; height, 1.86 ± 0.06 m) were studied. Eleven subjects were right-handed, and 10 were left-handed. After completing history and informed consent forms, each pitcher was tested in an indoor laboratory with a method similar to previous studies.[1,6,8-12,15,16,20,21] Reflective markers (2.5-cm diameter) were placed bilaterally on the proximal end of the third metatarsal, lateral malleolus, lateral femoral epicondyle, greater femoral trochanter, lateral superior tip of the acromion, and lateral humeral epicondyle. A marker was also placed on the ulnar styloid of the glove hand. Unlike most of the previous studies, additional reflective markers were placed on the ulnar styloid, radial styloid, and distal end of the third metacarpal of the throwing hand to determine wrist and forearm motions. Marker setup is shown in Figure 1.

After warming up with his normal routine, each pitcher was tested pitching from an indoor mound (Athletic Training Equipment Company, Santa Cruz, Ariz) to a strike zone ribbon above home plate located the regulation distance away (18.44 m). Each subject was asked to throw all of the pitch types that he uses. All subjects (n = 21) threw fastballs, most subjects threw curveballs (n = 20) and change-ups (n = 19), and some threw sliders (n = 6). Each subject threw 8 fastballs and 5 trials of each of his other pitch types. The motions of the reflective markers were tracked with a 6-camera, high-speed (240-Hz), automatic digitizing system (Motion Analysis Corporation, Santa Rosa, Calif). Position data were then filtered with a 13.4-Hz low-pass filter. In each frame, the locations of the throwing shoulder and throwing elbow were translated from the surface marker to the joint center with a method

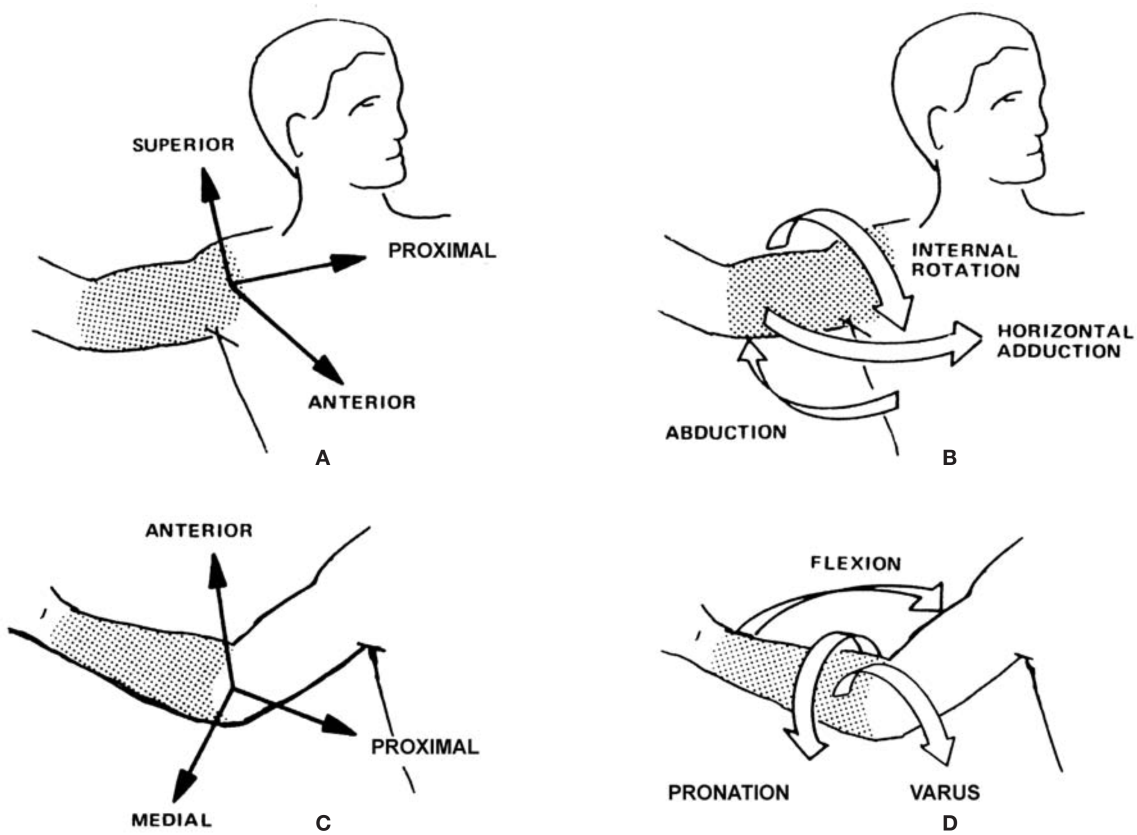

Figure 2. Definition of kinetic parameters: A, forces applied by the trunk to the upper arm at the shoulder; B, torques applied by the trunk to the upper arm about the shoulder; C, forces applied by the upper arm to the forearm at the elbow; D, torques applied by the upper arm to the forearm about the elbow. Modified from Fleisig et al[12] (with permission).

previously described.[6,9] The throwing wrist was calculated as the midpoint of the medial and lateral wrist markers.

Linear acceleration of each marker and joint center was calculated using the 5-point central difference method from the digitized motion data. Inertial properties of the hand, forearm, and upper arm were calculated from cadaveric data[2,5] and scaled for body size.[4] The baseball was modeled as a 142-g point mass at the metacarpal marker before it was released and was omitted from the model after it was released. Joint resultant forces and torques at the wrist were calculated with inverse dynamics and free-body equations of the hand and ball. Subsequently, elbow and then shoulder kinetics were calculated using inverse dynamics and free-body equations as previously described.[9-12] After the dynamics were calculated, elbow and shoulder kinetics were transformed into clinically relevant noninertial orthogonal reference frames (Figure 2). For each trial, maximum values were analyzed for 9 kinetic parameters: wrist flexion torque, forearm pronation torque, elbow varus torque, elbow flexion torque, elbow proximal force, shoulder internal rotation torque, shoulder horizontal adduction torque, shoulder abduction torque, and shoulder proximal force.

Seventeen position parameters were calculated for each pitch, with methods previously described.[1,6,8-12,20] These parameters, illustrated in Figure 3, were wrist extension, elbow flexion, shoulder external rotation, knee flexion, stride length, foot position, and foot angle at the instant of lead foot contact; maximum values of wrist extension, forearm supination, elbow flexion, shoulder horizontal adduction, and shoulder external rotation; and elbow flexion, shoulder abduction, shoulder horizontal adduction, forward trunk tilt, lateral trunk tilt, and knee flexion at the instant of ball release. Five velocity parameters and their corresponding timing were also calculated as previously described.[1,3,8,9,11,12] Maximum velocities of the pelvis and upper trunk were calculated as the 3-dimensional transverse angular velocity of the segment (Figure 3). Maximum velocities of elbow extension and shoulder internal rotation were calculated as the time derivative of angle. Ball velocity was measured with a Jugs Tribar Sport radar gun (Jugs Pitching Machines Co, Tualatin, Ore).

Kinetic and kinematic parameters were grouped according to when they occurred in the pitch. Key events in the pitch and the phases defined between them are illustrated in Figure 4. The arm cocking phase spanned the time from front foot contact to maximum shoulder external rotation. The arm acceleration phase was from maximum shoulder external rotation until ball release. The arm deceleration phase was from ball release until maximum shoulder internal rotation. Data for the 3 fastest strikes of each type thrown by each subject were averaged for further analysis.

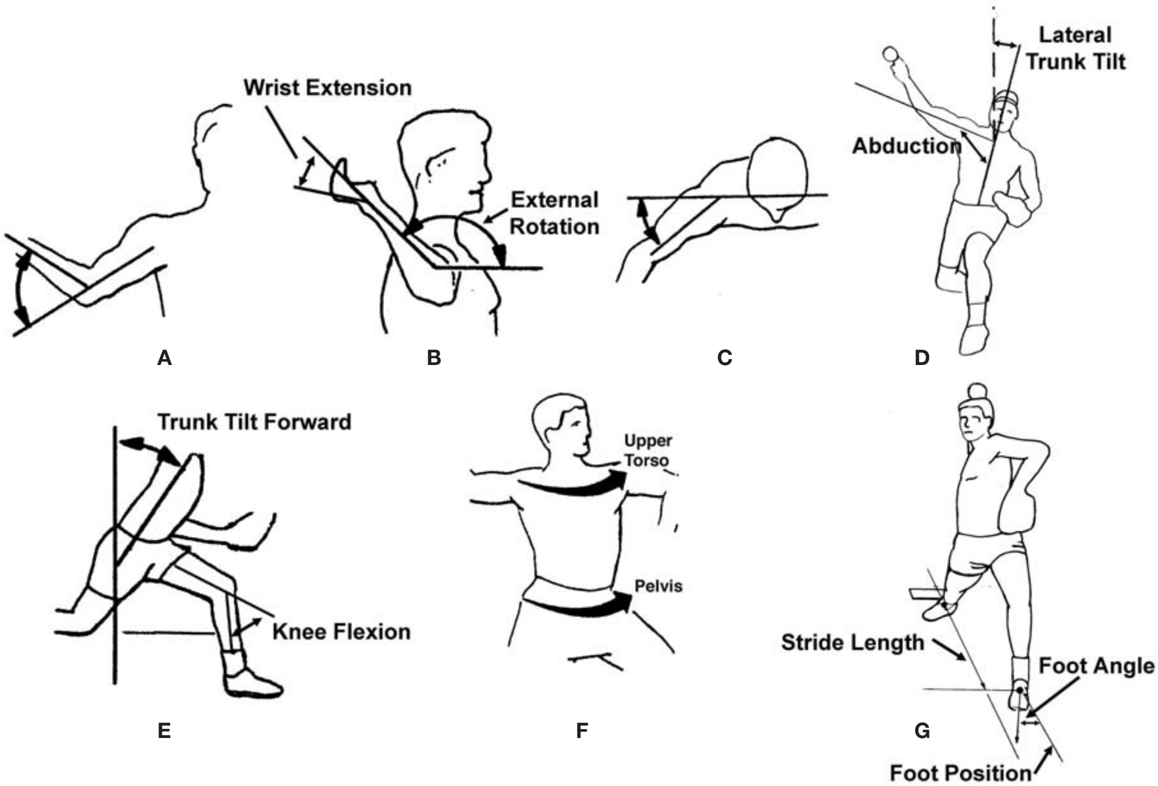

Figure 3. Definition of kinematic parameters: A, elbow flexion; B, wrist extension and shoulder external rotation; C, shoulder horizontal adduction; D, shoulder abduction and lateral trunk tilt; E, knee flexion and forward trunk tilt; F, pelvis angular velocity and upper trunk angular velocity; G, stride length, foot angle, and foot position. Modified from Fleisig et al[12] (with permission).

For each parameter, a repeated-measures analysis of variance (ANOVA) was used to evaluate differences among the 4 types of pitches. All statistical testing was performed with SigmaStat software, version 2.03.0 (Systat Software Inc, Richmond, Calif). When a subject did not throw a particular type of pitch, SigmaStat used a general linear model to handle the missing data. This approach constructed hypothesis tests using the marginal sums of squares (also commonly called the type III or adjusted sums of squares). Because a relatively large number (n = 35) of repeated-measures ANOVAs were run, a relatively low level ($P < .01$) was used to reduce the risk of type I errors. For parameters with significant differences, a Tukey post hoc test ($P < .01$) was used to identify significant differences between pairs of pitch types.

RESULTS

Kinetic data are shown in Table 1. The curveball produced less elbow proximal force than did the fastball and less shoulder horizontal adduction torque and shoulder proximal force than did the slider. The slider produced significantly more shoulder horizontal adduction torque than did the fastball. The change-up produced significantly less internal rotation torque, horizontal adduction torque, adduction torque, and proximal force at the shoulder than did the other 3 pitches. The change-up also produced significantly less proximal force compared to the fastball, slider, and curveball; significantly less varus torque at the elbow compared with the fastball and curveball; and significantly less elbow flexion torque compared with the curveball. Wrist flexion torque and forearm pronation torque were quite small and showed no significant differences among the pitch types.

Kinematic data are shown in Table 2. Most significant differences among pitches were at the instant of ball release. Elbow flexion, shoulder horizontal adduction, and knee flexion were greater in the change-up than in the other pitches. During arm cocking, wrist extension was greater in the fastball and change-up than in the curveball. The curveball demonstrated greater forward and lateral trunk tilts compared with the fastball and change-up.

Magnitude and timing of velocities are shown in Table 3. Ball velocity decreased significantly from fastball to slider to change-up to curveball. Although the curveball had the lowest ball velocity, it was the change-up that generated significantly less angular velocities of the upper trunk, elbow, and shoulder compared with the 3 other pitch types. There were no significant differences in any of the temporal parameters.

DISCUSSION

There was only one significant kinetic difference (elbow proximal force) between the fastball and curveball. There

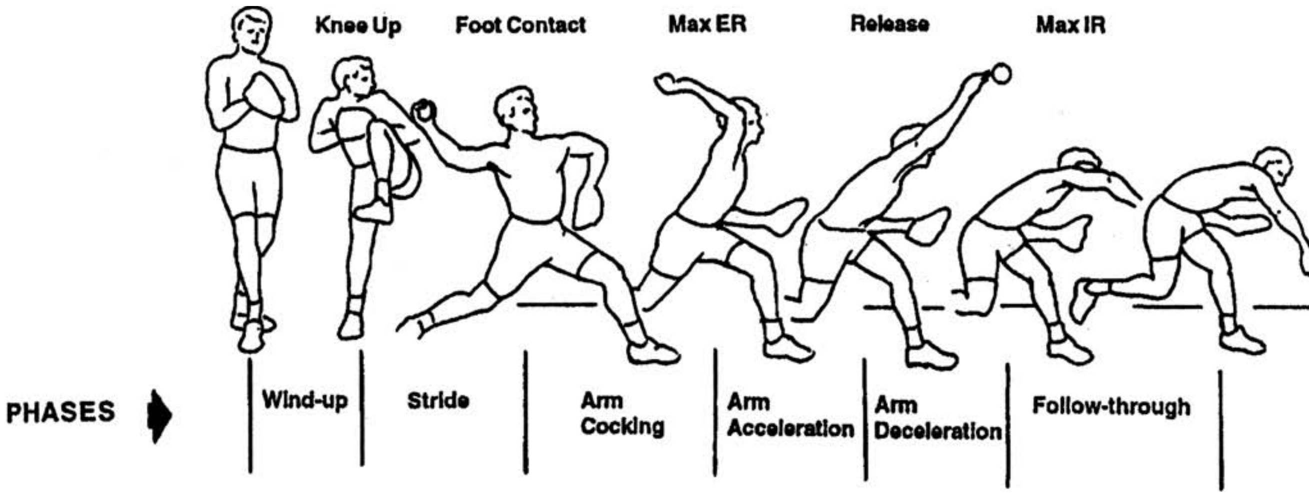

Figure 4. Phases and key events of a pitch. ER, external rotation; IR, internal rotation. Modified from Fleisig et al[12] (with permission).

TABLE 1
Joint Kinetics Compared Among Pitch Types[a]

	Fastball (n = 21)	Curveball (n = 20)	Change-up (n = 19)	Slider (n = 6)	Comparison[b]
Arm cocking phase					
Elbow varus torque, N·m	82 ± 13	79 ± 14	71 ± 12	81 ± 5	b, f
Shoulder internal rotation torque, N·m	84 ± 13	81 ± 14	73 ± 13	84 ± 6	b, e, f
Arm acceleration phase					
Wrist flexion torque, N·m	6 ± 4	7 ± 4	6 ± 4	7 ± 2	
Forearm pronation torque, N·m	5 ± 4	5 ± 3	3 ± 1	3 ± 1	
Elbow flexion torque, N·m	40 ± 9	41 ± 16	32 ± 9	37 ± 14	f
Elbow proximal force, N	988 ± 110	934 ± 103	857 ± 138	1040 ± 53	a, b, e, f
Shoulder horizontal adduction torque, N·m	111 ± 29	109 ± 20	98 ± 20	130 ± 35	b, c, d, e, f
Shoulder proximal force, N	1056 ± 157	998 ± 155	910 ± 169	1145 ± 113	b, d, e, f
Arm deceleration phase					
Shoulder adduction torque, N·m	110 ± 27	116 ± 34	100 ± 23	127 ± 33	b, e, f

[a]Data are means ± SDs.
[b]All comparisons significant at $P < .01$. a, fastball versus curveball; b, fastball versus change-up; c, fastball versus slider; d, slider versus curveball; e, slider versus change-up; f, change-up versus curveball.

was only one significant kinetic difference (shoulder horizontal adduction torque) between the fastball and the slider, but other kinetic differences might have been significant with a greater sample size of slider data. Shoulder and elbow kinetics were significantly less for the change-up compared with the fastball, curveball, and slider. Thus, first inspection of the kinetic data suggests that the change-up may have the lowest injury risk potential to the shoulder and elbow, and the fastball and curveball may have similar injury risk potential due to similar joint loads. However, because there were differences in wrist and forearm motions between the fastball and curveball, the length, velocity, and force contribution of specific elbow ligaments, tendons, and other structures may be different between the 2 pitches. Specifically, elbow varus torque is produced by tension in the ulnar collateral ligament, compression in the radiocapitellar joint, and other tissue.[10] Calculation of varus torque by inverse dynamics shows the total resultant load produced at the elbow but does not address changes in ulnar collateral ligament tension and radiocapitellar compression that may occur with different elbow flexion, forearm supination, and wrist angles. Modeling of the structures within the upper extremity is beyond the scope of the current study, so further research is needed to test this theory. The current study and previous studies showed kinetic and kinematic differences between the fastball and slider, but most of these differences were statistically insignificant. With data from more

TABLE 2
Body Position Parameters Compared Among Pitch Types[a]

	Fastball (n = 21)	Curveball (n = 20)	Change-up (n = 19)	Slider (n = 6)	Comparison[b]
Lead foot contact					
Elbow flexion, deg	86 ± 16	89 ± 13	84 ± 16	80 ± 10	f
Shoulder external rotation, deg	46 ± 25	45 ± 29	45 ± 26	41 ± 27	
Knee flexion, deg	38 ± 9	37 ± 9	35 ± 9	34 ± 11	b, e
Stride length between ankles, % height	70 ± 4	70 ± 4	70 ± 4	71 ± 2	
Foot position, m	−0.19 ± 0.14	−0.23 ± 0.13	−0.20 ± 0.14	−0.18 ± 0.14	a, f
Foot angle, deg	19 ± 11	19 ± 11	18 ± 9	7 ± 8	
Arm cocking phase, deg					
Maximum wrist extension	56 ± 8	43 ± 13	57 ± 8	45 ± 14	a, f
Maximum forearm supination	14 ± 22	22 ± 20	13 ± 26	25 ± 13	
Maximum elbow flexion	99 ± 11	101 ± 10	98 ± 12	96 ± 6	
Maximum shoulder horizontal adduction	18 ± 6	19 ± 6	21 ± 6	16 ± 6	b, e
Maximum shoulder external rotation	178 ± 7	180 ± 6	177 ± 8	183 ± 10	
Ball release, deg					
Elbow flexion	29 ± 6	29 ± 6	33 ± 6	26 ± 4	b, e, f
Shoulder abduction	96 ± 9	98 ± 10	99 ± 10	94 ± 9	b, d, e
Shoulder horizontal adduction	12 ± 8	14 ± 7	16 ± 7	11 ± 10	b, e, f
Forward trunk tilt	33 ± 7	37 ± 8	33 ± 8	36 ± 9	a, f
Lateral trunk tilt	23 ± 9	26 ± 10	19 ± 8	22 ± 9	a, d, f
Knee flexion	29 ± 12	32 ± 11	39 ± 12	27 ± 10	b, e, f

[a]Data are means ± SDs.
[b]All comparisons significant at $P < .01$. a, fastball versus curveball; b, fastball versus change-up; c, fastball versus slider; d, slider versus curveball; e, slider versus change-up; f, change-up versus curveball.

TABLE 3
Magnitude and Timing of Maximum Velocities Compared Among Pitch Types[a]

	Fastball (n = 21)	Curveball (n = 20)	Change-up (n = 19)	Slider (n = 6)	Comparison[b]
Maximum pelvis angular velocity, deg/s	600 ± 110	560 ± 90	540 ± 90	550 ± 40	a, b
Time of maximum pelvis angular velocity, % delivery complete	30 ± 17	34 ± 17	29 ± 15	38 ± 18	
Maximum upper trunk angular velocity, deg/s	1120 ± 90	1070 ± 90	1020 ± 70	1110 ± 60	a, b, e, f
Time of maximum upper trunk angular velocity, % delivery complete	50 ± 9	51 ± 6	49 ± 10	52 ± 9	
Maximum elbow extension velocity, deg/s	2210 ± 260	2160 ± 230	1970 ± 210	2260 ± 160	b, e, f
Time of maximum elbow velocity, % delivery complete	93 ± 3	93 ± 3	94 ± 2	93 ± 3	
Maximum shoulder internal rotation velocity, deg/s	6520 ± 950	6480 ± 860	5800 ± 780	6360 ± 720	b, e, f
Time of maximum internal rotation velocity, % delivery complete	104 ± 2	104 ± 2	105 ± 2	102 ± 2	
Ball velocity, m/s	35 ± 1	29 ± 1	30 ± 1	31 ± 1	a, b, c, d, f

[a]Data are means ± SDs. Timing parameters are expressed on a normalized time scale, where 0% was the time of lead foot contact and 100% was the time of ball release.
[b]All comparisons significant at $P < .01$. a, fastball versus curveball; b, fastball versus change-up; c, fastball versus slider; d, slider versus curveball; e, slider versus change-up; f, change-up versus curveball.

subjects who throw a slider, some of these differences may become significant. Furthermore, pitchers and coaches talk about the unique ball grip and forearm tension when throwing a slider, which may imply that there are other biomechanical differences between these pitches that could not be detected with the current methods. Again, this is an issue beyond the scope of the current study, and modeling research might indicate unique forearm and elbow stresses with the slider.

Kinematic differences among pitch types are important not only for safety but also for performance considerations. If a pitcher has significant kinematic differences between pitch types, he may need more neuromuscular training to achieve consistency and proficiency. Furthermore, it should be noted that the purpose of varying pitches is to fool the batter and throw off his timing. A common problem of unsuccessful pitchers is having different mechanics among pitch types, which allows batters to recognize pitch type early. Data from the current study showed that collegiate pitchers altered their arm velocities among the pitches, but it is doubtful that a batter would be looking at this or be able to perceive this. On the other hand, the differences reported in forearm supination, trunk tilt, and knee flexion may be detected by batters and allow them to prepare to hit the incoming pitch. Thus, a collegiate pitcher should strive to minimize differences in forearm, trunk, and knee angles among pitches. Although a pitcher might desire to eliminate all positional differences between his fastball and off-speed pitches, this might not be possible. Matsuo et al[15] demonstrated that decreased trunk tilt and increased front knee flexion were characteristic of lower velocity fastballs; it might be that these changes are also needed to throw slower change-ups and curveballs. Although some differences might be unavoidable, it is our unproven belief that the kinematic differences between the fastball and off-speed pitches are less in pitchers who reach professional baseball than in collegiate pitchers. Future research on professional pitchers could confirm the importance of minimizing these differences.

The methods of the current study were similar to those used by Escamilla et al[8] to compare kinematics among various types of pitches. In that study, 16 collegiate baseball pitchers were tested. All 16 subjects in the previous study threw a fastball, change-up, and curveball, whereas 7 threw the slider. Overall, kinematic differences in the current study were very similar to the differences found in Escamilla et al.[8] One difference between these 2 studies was body position at the instant of ball release. In the current study, the trunk was tilted forward significantly more in the curveball than in the fastball and change-up. In Escamilla et al,[8] forward trunk tilt was greatest in the curveball and fastball and least in the change-up. Both Escamilla et al[8] and the current study demonstrated that front knee flexion at ball release was greatest in the change-up and least in the fastball. In the current study, knee flexion in the curveball and slider was similar to the fastball, but in Escamilla et al,[8] knee flexion in the curveball and slider was similar to the change-up. Thus, both studies found variations in knee flexion and trunk tilt among pitch types. The relatively few differences between the studies imply consistency in the ability to quantify pitch kinematics.

Sakurai et al[18] and Barrentine et al[1] also compared pitching kinematics between pitches. These studies focused on wrist and forearm motions more than the current study did by adding a long stick in the medial-lateral direction along the dorsal surface of the throwing wrist. Sakurai et al[18] tested 6 Japanese collegiate baseball pitchers throwing fastball and curveball pitches. Barrentine et al[1] studied 8 American collegiate pitchers throwing fastball, change-up, and curveball pitches. Both studies showed that the curveball had the most forearm supination, the most ulnar deviation at the wrist, and the least wrist extension. In the current study, the curveball demonstrated more forearm supination and less wrist extension than did the fastball or change-up; the wrist extension differences were statistically significant, but the supination differences were not. With a long stick on the wrist (as used by Sakurai et al[18] and by Barrentine et al[1]), the forearm kinematic data from the current subjects may have had less variation and therefore statistically significant differences, as in the previous studies.

Although the kinematic data from the current study were consistent with previous publications, magnitudes of kinetic parameters were noticeably different. Examples of such differences are evident in comparing fastball kinetics from the current study with the collegiate data in Fleisig et al.[11] In the arm cocking phase of the fastball pitch, elbow varus torque (82 ± 13 N·m in current study vs 55 ± 12 N·m in Fleisig et al[11]) and shoulder internal rotation torque (84 ± 13 N·m vs 58 ± 12 N·m) were noticeably greater in the current study. Maximal proximal forces at the elbow (988 ± 110 N vs 770 ± 120 N) and at the shoulder (1056 ± 157 N vs 910 ± 130 N) were also greater in the current study. Methods used in the current study were similar to the methods used in Fleisig et al[11] and other publications, except for the addition of the hand marker in the current study. Because previous studies did not include a marker on the hand, the masses of the ball (until release) and the hand were modeled at the wrist joint. Thus, increased kinetic values in the current study may be owing to the inclusion of wrist kinematics and improved location of the hand's mass and ball's mass. To test this theory, kinematic data in the current study were reanalyzed but with the mass of the hand and ball modeled at the wrist. Calculated values of elbow varus torque (65 ± 11 N·m), shoulder internal rotation torque (67 ± 12 N·m), elbow proximal force (854 ± 117 N), and shoulder proximal force (947 ± 166 N) were then closer to previous published data. Although the lower kinetic values of previous publications may have been less accurate, the conclusions from those studies most likely were not affected. For example, because fastball data for youth, high school, college, and professional pitchers in Fleisig et al were all analyzed with the hand and ball mass,[11] the findings that kinetics increased significantly with playing level are most likely still the proper conclusion. However, the inclusion of wrist biomechanics is important for the current study because of differences in wrist and forearm kinematics among pitch types, previously documented by Sakurai et al[18] and Barrentine et al.[1]

The current and previous biomechanical studies provide a solid understanding of kinetic and kinematic differences among various pitch types in collegiate pitchers. For youth and high school baseball, fastball kinematics has been previously reported,[11] but curveball, change-up, and slider data have not been published. Anecdotal evidence suggests that there is a wide variety in quality of instruction that youth pitchers have received, and there is a wide variety in how children attempt to throw breaking pitches.

In a study of 476 youth baseball players, pitchers who threw curveballs or sliders were more likely to experience shoulder pain or elbow pain, respectively.[14] In a study of high school baseball players requiring ulnar collateral ligament reconstruction, two thirds of the patients (16/24) self-reported that they began throwing curveballs before age 14.[17] In 2003, USA Baseball posted a position statement recommending that pitchers refrain from throwing breaking pitches (curveballs, sliders, etc) in competition until puberty (www.usabaseball.com/med_position_statement.html). Instead of throwing breaking pitches, the statement recommended that the youth pitcher focus on good mechanics, good control, a fast fastball, and a good change-up. The position statement also included other recommendations, such as pitch counts, physical fitness, periodization, and nutrition.

Future research is needed to quantify the kinetics and kinematics of various pitch types in youth, high school, and professional baseball pitchers. The current research provided results and implications specifically for the collegiate-level pitcher.

CONCLUSION

The change-up appears to be the least stressful and safest pitch to throw; however, the collegiate pitcher should work to minimize positional differences in the forearm, trunk, and knee that might tip off a batter that the pitch is a change-up. The similar magnitude in elbow and shoulder kinetics between the fastball and curveball implies that throwing curveballs is no more dangerous for the college pitcher than is throwing fastballs. The increased forearm supination and increased wrist motion from radial deviation to ulnar deviation may or may not increase tension and injury risk in specific soft tissue, but such analysis was beyond the scope of the current study. Kinetic differences were seen between the slider and other pitches, but statistical significance of these differences could not be determined because of the limited number of subjects who threw sliders.

If future biomechanical or epidemiological data identify increased loads or risks with specific pitches, these should be considered at that time. Based on the current body of knowledge, we support the use of the fastball, curveball, change-up, and slider among college-level pitchers.

ACKNOWLEDGMENT

The authors thank Nigel Zheng, PhD, Steve Barrentine, MS, Derek Weichel, and Monique Butcher, PhD, for their assistance with this study.

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