Biomechanical Comparison of Baseball Pitching and Long-Toss: Implications for Training and Rehabilitation

Following a shoulder or elbow injury or surgery, a baseball pitcher or position player must progress through a multiphase rehabilitation program to return to competition. Such programs often begin with exercises to restore range of motion and strength of the affected joint, followed by more functional and aggressive rehabilitation exercises. The latter phases incorporate functional exercises, such as plyometrics and high-speed training, to prepare the player to throw. An interval long-toss throwing program is the hallmark of the return-to-activity phase. The interval throwing program starts skeletally mature players at a throwing distance of 45 ft (14 m) and progressively increases it to 180 ft (55 m). For all flat-ground throws, the player is verbally instructed to use “crow-hop” footwork, to throw “on a line” (a hard throw with a low trajectory), and to use proper mechanics. The use of proper mechanics—the mechanics used by healthy players—is critical aspect of the interval throwing program. It has been suggested that pitching coaches and sports biomechanists provide a valuable service on a rehabilitation team to ensure proper mechanics. Thus an understanding of healthy throwing mechanics is essential for the rehabilitation of an injured player. If the player is a pitcher, the flat-ground throwing phases of the rehabilitation program are followed by throwing off the mound. During the off-the-mound throwing phase, a pitcher progresses from partial-effort to full-effort pitches. Theoretically, the progression of throwing phases allows an injured athlete to gradually recover his arm flexibility, arm strength, and proper throwing mechanics. Interval throwing programs have been utilized to effectively return pitchers and position players to baseball.

**STUDY DESIGN:** Controlled laboratory study.

**OBJECTIVES:** To test for kinematic and kinetic differences between baseball pitching from a mound and long-toss on flat ground.

**BACKGROUND:** Long-toss throws from flat ground are commonly used by baseball pitchers for rehabilitation, conditioning, and training. However, there is controversy over the biomechanics and functionality of such throws.

**METHODS:** Seventeen healthy, college baseball pitchers pitched fastballs 18.4 m from a mound to a strike zone, and then 37 m, 55 m, and maximum distance from flat ground. For the 37-m and 55-m throws, participants were instructed to throw “hard, on a horizontal line.” For the maximum-distance throw, no constraint on trajectory was given. Kinematics and kinetics were measured with a 3-dimensional, automated motion analysis system. Repeated-measures analyses of variance, with post hoc paired t-tests, were used to compare the 4 throw types within pitchers.

**RESULTS:** At foot contact, the participant’s shoulder line was nearly horizontal when pitching from a mound and became progressively more inclined as throwing distance increased. At arm cocking, the greatest amount of shoulder external rotation (mean ± SD, 180° ± 11°), elbow flexion (109° ± 10°), shoulder internal rotation torque (101 ± 17 Nm), and elbow varus torque (100 ± 18 Nm) were measured during the maximum-distance throws. Elbow extension velocity was also greatest for the maximum-distance throws (2573°/s ± 203°/s). Forward trunk tilt at the instant of ball release decreased as throwing distance increased.

**CONCLUSION:** Hard, horizontal, flat-ground throws have biomechanical patterns similar to those of pitching and are, therefore, reasonable exercises for pitchers. However, maximum-distance throws produce increased torques and changes in kinematics. Caution is, therefore, advised in the use of these throws for rehabilitation and training.

**KEY WORDS:** crow-hop, elbow, interval throwing program, kinematics, shoulder

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Flat-ground throwing is also used to improve strength and conditioning of healthy baseball players, especially pitchers. Theoretically, long-distance flat-ground throwing would require the pitcher’s arm to generate greater force, torque, range of motion, and speed than pitching would. Therefore, long-distance, flat-ground throwing may be used to train a pitcher to have greater arm strength, arm flexibility, arm speed, and ultimately pitch speed. Throwing programs for healthy players vary greatly. Some programs limit throws to a specific distance (55 m, for example), while others include maximum-distance throws. Some programs require the players to throw on a line, while others recommend throwing on an arc.

Flat-ground throwing has been part of baseball rehabilitation and conditioning for decades. Recently, however, some have asked whether flat-ground throwing might be ineffective or even harmful for baseball pitchers and position players. There has also been controversy over limitations on throwing distance. While pitching biomechanics has been studied extensively, little is known about long-toss throwing biomechanics. In the only previous study on long-toss baseball throwing, Miyanishi et al. compared the kinematics of 24 college baseball players throwing a ball as far as possible. No previous study has compared the biomechanics of flat-ground throwing and pitching. Therefore, it is still not known whether baseball pitchers use similar kinematics and kinetics during long-toss and pitching. Thus, the theoretical benefits of long-toss for pitchers remain unsubstantiated. The purpose of this study was to compare the biomechanics of pitching and long-toss throwing. The present study tested the hypotheses that there are kinematic (motion) and kinetic (torque and force) differences in the throwing shoulder and elbow between pitching and throwing various flat-ground distances.

**METHODS**

**Pitchers from 3 college baseball teams were recruited for the study.**

Players who had been injured during the previous 12 months and those who pitched with sidearm or “submarine” mechanics were excluded. Seventeen baseball pitchers met the criteria and agreed to participate. All participants were experienced with long-toss, as all 3 colleges used long-toss in their conditioning and warm-ups. Each participant completed an informed consent form and provided medical history, physical information, and baseball background. The pitchers were (mean \( \pm \) SD) 20.6 \( \pm \) 1.2 years of age and 186 \( \pm \) 6 cm in height, and had a mass of 89 \( \pm \) 10 kg. The study was approved by The Institutional Review Board of St Vincent’s Health System, Birmingham, AL.

Each participant was tested during 2 sessions. For each session, 21 reflective markers (10 mm in diameter) were attached to the participant. This included markers attached bilaterally to the distal end of the third metatarsal, lateral malleolus, lateral femoral epicondyle, greater trochanter, lateral superior tip of the acromion, lateral humeral epicondyle, and...
Comparison of Position Data Among Throws

<table>
<thead>
<tr>
<th></th>
<th>Fastball Pitch (18.4 m)</th>
<th>37-m Throw</th>
<th>55-m Throw</th>
<th>Maximum-Distance Throw (80 ± 9 m)</th>
<th>Differences</th>
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<tbody>
<tr>
<td>Foot contact</td>
<td></td>
<td></td>
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<tr>
<td>Elbow flexion</td>
<td>78 ± 17</td>
<td>79 ± 18</td>
<td>79 ± 18</td>
<td>86 ± 20</td>
<td>c,e,f</td>
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<tr>
<td>Shoulder external rotation</td>
<td>53 ± 30</td>
<td>56 ± 28</td>
<td>60 ± 28</td>
<td>58 ± 26</td>
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<tr>
<td>Shoulder abduction</td>
<td>96 ± 10</td>
<td>98 ± 10</td>
<td>99 ± 10</td>
<td>98 ± 9</td>
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<tr>
<td>Shoulder horizontal abduction</td>
<td>21 ± 11</td>
<td>19 ± 12</td>
<td>19 ± 11</td>
<td>21 ± 11</td>
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<tr>
<td>Upper trunk tilt</td>
<td>6 ± 7</td>
<td>13 ± 9</td>
<td>15 ± 8</td>
<td>24 ± 8</td>
<td>a,b,c,d,e,f</td>
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<td>Pelvis angle</td>
<td>37 ± 12</td>
<td>37 ± 11</td>
<td>39 ± 11</td>
<td>40 ± 11</td>
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<tr>
<td>Front knee flexion</td>
<td>47 ± 9</td>
<td>46 ± 8</td>
<td>44 ± 7</td>
<td>42 ± 6</td>
<td>b,c,d,e,f</td>
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<tr>
<td>Stride length, % participant’s height</td>
<td>80 ± 4</td>
<td>79 ± 6</td>
<td>80 ± 6</td>
<td>80 ± 7</td>
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<tr>
<td>Foot position, cm</td>
<td>25 ± 12</td>
<td>16 ± 14</td>
<td>13 ± 15</td>
<td>5 ± 18</td>
<td>a,b,c,d,e,f</td>
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<tr>
<td>Arm cocking</td>
<td></td>
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<tr>
<td>Maximum elbow flexion</td>
<td>101 ± 11</td>
<td>103 ± 10</td>
<td>104 ± 11</td>
<td>109 ± 10</td>
<td>c,e,f</td>
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<tr>
<td>Maximum shoulder external rotation</td>
<td>174 ± 10</td>
<td>174 ± 10</td>
<td>176 ± 10</td>
<td>180 ± 11</td>
<td>c,d,e,f</td>
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<tr>
<td>Maximum shoulder horizontal adduction</td>
<td>17 ± 6</td>
<td>18 ± 7</td>
<td>18 ± 7</td>
<td>17 ± 7</td>
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<tr>
<td>Ball release</td>
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<tr>
<td>Shoulder abduction</td>
<td>88 ± 7</td>
<td>89 ± 9</td>
<td>89 ± 9</td>
<td>88 ± 8</td>
<td></td>
</tr>
<tr>
<td>Forward trunk tilt</td>
<td>34 ± 8</td>
<td>27 ± 8</td>
<td>25 ± 7</td>
<td>18 ± 8</td>
<td>a,b,c,d,e,f</td>
</tr>
<tr>
<td>Lateral trunk tilt</td>
<td>25 ± 8</td>
<td>24 ± 8</td>
<td>24 ± 8</td>
<td>26 ± 7</td>
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<tr>
<td>Front knee flexion</td>
<td>37 ± 13</td>
<td>36 ± 12</td>
<td>33 ± 13</td>
<td>31 ± 12</td>
<td>b,c,d,e,f</td>
</tr>
</tbody>
</table>

*Values are mean ± SD degrees, except where otherwise indicated.
*Analysis of variance revealed significant difference among throws (P<.01). Post hoc t tests indicated significant differences between (a) pitch and 37-m throw, (b) pitch and 55-m throw, (c) pitch and maximum-distance throw, (d) 37-m and 55-m throws, (e) 37-m and maximum-distance throws, and (f) 55-m and maximum-distance throws.

For the first testing session, the motion capture system was set up in the outdoor setup was reliable and the calibration coefficients were similar to values recorded during indoor testing. Distances were measured and marked from the throwing area. The x-axis was the direction of throwing, the z-axis was the vertical axis, and y was their cross product \((z \times x)\). Participants wore tight shorts, socks, and cleats. Reflective markers were attached to a pair of participants, who, by throwing to each other, took as much time as they needed to warm up. The pair started by throwing close to each other and progressively increased their distance apart, until they were throwing near their maximum distance. Each participant was then tested for five 37-m (120-ft), five 55-m (180-ft), and five maximum-distance throws to a coach. Each pitcher completed a total of 15 throws (5 throws at 3 distances), which provided a sufficient sample of data, without allowing the second pitcher in the pair to cool down while waiting his turn to be tested. Each participant was allowed to use the crow-hop footwork that he was comfortable with, as there is no description of crow-hop footwork in the published literature, and coaches, physical therapists, and athletic trainers have given varied opinions. While most agree that crow-hop footwork is a sequence of steps of the front foot, back foot, then front foot, there is no consensus on whether the back foot steps behind, in front, or next to the front foot. The participant was instructed to throw “hard, on a horizontal line,” when performing the 37-m and 55-m throws. The participant was told to get the maximum distance on his final 5 throws, with no constraints on trajectory.

The second testing session took place in an indoor biomechanics laboratory. The 8 cameras were mounted on the walls surrounding a portable pitching mound (FIGURE, ONLINE VIDEO). A home plate strike
Comparison of Peak Velocity Data Among Throws*

<table>
<thead>
<tr>
<th></th>
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<th>55-m Throw</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Pelvis angular velocity, °/s</td>
<td>568 ± 67</td>
<td>586 ± 69</td>
<td>602 ± 73</td>
<td>621 ± 84</td>
<td>a,b,c,d†</td>
</tr>
<tr>
<td>Upper trunk angular velocity, °/s</td>
<td>120 ± 99</td>
<td>1141 ± 100</td>
<td>1153 ± 99</td>
<td>1179 ± 98</td>
<td>a,b,c,d†</td>
</tr>
<tr>
<td>Shoulder internal rotation velocity, °/s</td>
<td>7640 ± 1173</td>
<td>7590 ± 1214</td>
<td>8139 ± 1609</td>
<td>8040 ± 1211</td>
<td></td>
</tr>
<tr>
<td>Elbow extension velocity, °/s</td>
<td>2480 ± 255</td>
<td>2492 ± 204</td>
<td>2540 ± 176</td>
<td>2603 ± 164</td>
<td>b,c†</td>
</tr>
<tr>
<td>Ball velocity, m/s</td>
<td>37 ± 2</td>
<td>37 ± 2</td>
<td>37 ± 2</td>
<td>36 ± 2</td>
<td></td>
</tr>
</tbody>
</table>

*Values are mean ± SD.

†Analysis of variance revealed significant difference among throws (P<.01). Post hoc t tests indicated significant differences between (a) pitch and 55-m throw, (b) pitch and maximum-distance throw, (c) 37-m and maximum-distance throw, and (d) 55-m and maximum-distance throw.

The mean ± SD value for the maximum-distance throw among the 17 participants was 80 ± 9 m (262 ± 30 ft) and the range was 65 to 96 m (213-315 ft). Differences in position parameters are shown in Table 1. There were 4 significant differences at the instant of foot contact: elbow flexion was greatest for the maximum-distance throw, and, as throwing distance increased from pitching to maximum distance, upper trunk tilt increased, while front knee flexion and foot position decreased. When the arm was in the cocked position, elbow flexion and shoulder external rotation were greatest for the maximum-distance throw. At the time of ball release, as throwing distance increased, both forward trunk tilt and front knee flexion decreased.

Differences in velocity parameters are shown in Table 2. The pelvis and upper trunk rotational velocities were greatest for the maximum-distance throw. They were also significantly greater in the 55-m throws compared to the pitch. The elbow extension velocity was significantly greater for the maximum-distance throw than for the other throw types.

RESULTS

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other throws.

The pitching biomechanics of the cur

rent study was consistent with previously

published college pitching data.1,3,15,17,26

Flat-ground biomechanics in the current

study showed some of the patterns found

by Miyanishi et al.20 At the time of foot

contact, both studies found significantly

greater lateral trunk tilt (9°), while the

current study did not find significant dif

ferences for these parameters.

The pitching biomechanics of the cur

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Elbow Injury Mechanisms and

Rehabilitation

Previous studies have shown that maxi

mum elbow varus torque in pitching oc

curs near the time of maximum shoulder external rotation and that this torque is associated with maximum tensile force in the ulnar collateral ligament (UCL).3,11,27 Repetition of high force in the UCL associated with high varus torque can lead to gradual attenuation of the UCL.5,18 Thus the progression of throwing phases during rehabilitation after UCL surgery should allow the athlete to regain his pitching mechanics, while progressively loading the UCL graft. Because the greatest elbow varus torque occurred during maximum-distance throwing, these throws should be avoided following UCL reconstruction or at least delayed until the clinician has found that the UCL graft has adequately healed. Similarly, caution is advised for maximum-distance throwing in rehabili

tation following chondral defects in the lateral elbow, as varus torque is as

associated with compressive force between the radial head and the capitellum.14,23,27 Osteophytes in the posteromedial elbow result from varus torque during rapid el

bow extension.2,3,14,27 Because maximum-distance throws exhibited both the greatest varus torque and the greatest elbow extension velocity, such throws should not be used early in rehabilitation after posterior medial osteophyte removal.

Table 3

Comparison of Joint Forces and Torques Among Throws*

<table>
<thead>
<tr>
<th></th>
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<tr>
<td>Arm cocking</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elbow varus torque, Nm</td>
<td>92 ± 19</td>
<td>90 ± 18</td>
<td>95 ± 19</td>
<td>100 ± 18</td>
<td>a,b,c†</td>
</tr>
<tr>
<td>Shoulder internal rotation torque, Nm</td>
<td>94 ± 18</td>
<td>92 ± 17</td>
<td>96 ± 18</td>
<td>100 ± 18</td>
<td>a,b,c†</td>
</tr>
<tr>
<td>Ball release</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elbow flexion torque, Nm</td>
<td>47 ± 5</td>
<td>47 ± 8</td>
<td>47 ± 8</td>
<td>48 ± 8</td>
<td></td>
</tr>
<tr>
<td>Shoulder proximal force, N</td>
<td>1172 ± 159</td>
<td>1087 ± 184</td>
<td>1139 ± 202</td>
<td>1092 ± 129</td>
<td></td>
</tr>
</tbody>
</table>

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RESULTS

The data supported the hypothesis that there are kinematic and kinetic differences among the 4 throw types tested: pitching (18.4 m) from a mound, flat-ground throwing on a horizontal line at relatively short (37 m) distance, flat-ground throwing on a horizontal line at medium (55 m) distance, and flat-ground throwing at long (maximum) distance. As throwing distance increased, the player used a more inclined (more upward trunk tilt) position at foot contact. Also, as throwing distance increased, the player seemed to rely less on rotation in the sagittal plane (less forward trunk tilt and less knee flexion) and more on rotation in the transverse plane (greater pelvis angular velocity, upper trunk angular velocity, elbow flexion, and elbow extension velocity). Longer throws also produced greater elbow and shoulder torques in the arm-cocked position. The greater rotations in the transverse plane might have been caused by the greater arm-cocking torques; but this cause-and-effect relationship was beyond the focus of the current study. There were a greater number of significant differences between the maximum-distance throws and the other throws.
Shoulder Injury Mechanisms and Rehabilitation

During arm cocking, a pitcher’s shoulder is abducted, horizontally abducted, and externally rotated. These motions produce tension in the shoulder’s anterior capsule.\textsuperscript{14,27} The current study reported no differences in abduction or horizontal abduction among the different throws; however, there was increased maximum shoulder external rotation for maximum-distance throws. Maximum-distance throws also produced the greatest internal rotation torque, which occurred near the time of maximum shoulder external rotation. Because of the increased shoulder external rotation and shoulder internal rotation torque, maximum-distance throwing should be avoided or delayed in rehabilitation after procedures such as anterior capsular plication, capsulolabral repair, or labral repair, until adequate tissue healing has occurred. Excessive external rotation of the abducted shoulder is also the mechanism for symptoms of internal impingement of the infraspinatus and supraspinatus.\textsuperscript{30} Therefore, caution is advised for use of maximum-distance throwing in the rehabilitation of infraspinatus injury.

While certain aspects of pitching mechanics vary among successful pitchers, shoulder abduction is consistently near 90° at both foot contact and ball release.\textsuperscript{7,10,15} Excessive abduction may result in subacromial impingement of the bursa. Insufficient abduction is also a risk factor due to misalignment of force vectors among the deltoid, rotator cuff, and other shoulder stabilizers. Because no differences were reported in shoulder abduction among the various throws in the current study, there is no specific concern in throw types for rehabilitation from these injuries.

Fleisig et al\textsuperscript{14} described the mechanism of injury for a superior labral anterior-to-posterior (SLAP) lesion as distal force applied by the long head of the biceps to the superior labrum. This biceps force is applied at its origin, near the time of ball release, when the biceps is contracting to both resist glenohumeral distraction and decelerate elbow extension. Burkhart and Morgan\textsuperscript{1} proposed an alternate SLAP lesion mechanism, in which the biceps tendon “peels back” the anterior labrum. Shepard et al\textsuperscript{12} measured in vitro strength of the biceps-labral complex during both the distal force and peel-back mechanisms, and concluded that SLAP lesions most likely occur from repetition of both peel-back and distal forces. Shoulder external rotation and shoulder internal rotation torque may be related to the peel-back mechanism of the cocked arm, and shoulder proximal force and elbow flexion torque may be related to the biceps pull-out force near the time of ball release. Although the current study found no differences in ball release kinetics (shoulder proximal force and elbow flexion torque), both shoulder external rotation and shoulder internal rotation torque were greatest in maximum-distance throws. Thus longer distance throwing should be delayed until the clinician feels that the glenoid labrum has had adequate time to heal. Maximum-distance throws may create the largest peel-back forces and should be avoided, or at least delayed, after SLAP repair.

Near the time of ball release, a large proximal force is produced at the shoulder to resist distraction. The combination of this proximal force and the rapid internal rotation velocity at the shoulder may produce a grinding of the humeral head against the anterior glenoid labrum.\textsuperscript{14} The current study found no differences in proximal force or internal rotation velocity among throw types. However, because maximum-distance throws were identified in the current study as being the most stressful to the anterior labrum during arm cocking, caution is advised for use of maximum-distance throws after any anterior labrum injury.

Training

It has often been hypothesized that long-distance throwing is beneficial to the throwing athlete for increasing flexibility, ball speed, arm strength, and endurance. A previous comparison of adult pitchers with high versus low ball velocity demonstrated 3 kinematic differences.\textsuperscript{19} Namely, pitchers with high ball velocity had greater maximum shoulder external rotation, forward trunk tilt at the time of ball release, and lead knee extension velocity. For longer throws, the current study found greater maximum shoulder external rotation but less forward trunk tilt. Furthermore, the current study found no differences in ball velocity for various throw distances, and approximately 10° of knee extension from foot contact to ball release for all throws. Thus the current study did not find greater similarity between particular distances of throws and the pitching mechanics of pitchers with high ball velocity.

In another study investigating changes within individual pitchers, several characteristics correlated with greater ball velocity.\textsuperscript{22} Kinetic values near the time of ball release (elbow flexion torque, shoulder proximal force, and elbow proximal force) increased with pitch velocity. For pitches with higher ball velocity, at the time of ball release, pitchers displayed decreased shoulder horizontal adduction, decreased shoulder abduction, and increased forward trunk tilt. The current study showed no differences among throw types in ball velocity, kinetics at the time of ball release, shoulder horizontal adduction, or abduction. Forward trunk tilt decreased with throwing distance. Thus, the current study did not indicate that particular throwing distances were superior in training to increase ball velocity.

The current study did find greater range of motion (maximum shoulder external rotation), speed (angular velocities of the pelvis, upper trunk, and elbow), and arm torque (elbow varus and shoulder internal rotation) in long-toss, which indicates that these throws may be beneficial in training. However, long-distance throws also produced changes in throwing mechanics at foot contact (up-
hurl trunk tilt and foot position) and at ball release (forward trunk tilt and front knee flexion). Furthermore, maximum-distance throws produced the greatest elbow and shoulder torques, without any change in ball velocity, making these the least efficient throws, as they produced the most torque for comparable ball velocity. The benefits or detriments of long-toss cannot truly be determined without prospective studies comparing performance and safety between groups trained with and without long-toss.

Limitations and Future Direction
The current study’s findings suggest that the 55-m distance may be a good choice for the longer throw on a line, as all participants were able to throw this distance without increasing the ball trajectory. With unconstrained trajectories, all participants threw 65 m or greater. However, the fact that only 3 distances (37 m, 55 m, and maximum distance) were tested for flat-ground throws was a limitation of the current study. Also, the effects of throwing distance and trajectory were not separated. Studying players with a variety of crow-hop techniques and proficiency would also be valuable. Data from throws for a greater variety of players and distances, with different trajectories and throwing techniques, are needed to determine optimal long-toss throwing distances for college pitchers.

The current study used only healthy pitchers, even though flat-ground long-toss is relevant for injury rehabilitation. As stated above, players in rehabilitation throwing programs are instructed to use proper throwing mechanics, and the current study provides proper throwing data based upon a sample of healthy college pitchers. Future studies of player rehabilitation would be helpful to determine whether certain injuries lead to mechanical compensations and adjustments in throwing mechanics.

The current study included baseball players from only 1 level (college) and 1 position (pitcher), which was also a limitation. To enhance our understand-

ing of throwing biomechanics, data are needed for baseball players from a range of levels, various positions, and more distances. Skeletally immature throwers may require specific consideration due to poor mechanics and open growth plates. On the other end of the spectrum, professional players may require specific consideration due to their strength, length of season, and abilities to generate ball velocity, ball distance, and joint torque.

Both clinical and longitudinal studies would prove valuable. Clinical studies could be designed to compare baseball success of groups of athletes after various long-toss programs. Longitudinal studies could measure throwing biomechanics at various time intervals for players involved with various rehabilitation or training protocols.

CONCLUSION

Based on the results of this study, a college baseball pitcher should not be expected to throw long, flat throws without kinematic and kinetic differences in his pitching biomechanics. As reported here, the increased kinetic and kinematic values with increased throw distance support our clinical experience that long-toss too early in rehabilitation may lead to shoulder and or elbow soreness. The use of long-toss in rehabilitation should be under the supervision of a clinician to monitor tissue healing and joint range of motion. It is the opinion of the authors that long-toss throwing on a line is a safe exercise for rehabilitation and training; however, the use of long-toss throwing for maximum distance may not be beneficial. This advice against maximum-distance throwing is based upon the high magnitudes of elbow varus torque, shoulder internal rotation torque, and upper trunk tilt, and low magnitude of forward trunk tilt. More biomechanical data are needed to quantify various long-toss throwing distances, techniques, and protocols for players of various ages, skill levels, and health levels. Performance and safety data after various long-toss throwing programs may be valuable in determining clinical efficacy.

KEY POINTS

FINDINGS: In a comparison of 4 types of throws (pitching from a mound and 3 long-toss throws from flat ground), shoulder and elbow angles and torques increased as throwing distance increased. Differences in leg and trunk kinematics were also noticed. The greatest number of differences was found between maximum-distance throwing and pitching, 37-m throws, and 55-m throws.

IMPLICATION: Because shoulder and elbow torques increase with throwing distance, progression of throwing during rehabilitation should be under the supervision of a physical therapist or other clinician, to monitor tissue healing and joint range of motion. While long-toss thrown on a line seems biomechanically sound for rehabilitation and training, the use of long-toss throws for maximum distance may be more harmful than beneficial.

CAUTION: Data were collected solely from healthy, college-age pitchers.

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