[Sports Physical Therapy]

Glenohumeral Range of Motion and Lower Extremity Flexibility in Collegiate-Level Baseball Players

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Background: The throwing motion results in unilateral increases in dominant arm external rotation (ER) range of motion (ROM). Trunk forward tilt at ball release is related to ball velocity. The relationship between lower quarter flexibility and dominant arm ROM is not known.

Hypothesis: There is a relationship between lower extremity flexibility and dominant arm ER ROM and total rotation ROM.

Study Design: Prospective cohort study.

Methods: Forty-two collegiate baseball pitchers were studied. Demographics, dominant arm, and bilateral glenohumeral ER and internal rotation (IR) ROM were measured. Lower quarter flexibility was assessed via sit-and-reach test. Total rotation motion (TRM) was calculated as ER + IR = TRM. Paired *t* tests examined differences between the dominant and nondominant arms for ER, IR, and TRM; Pearson product-moment correlation coefficients, shoulder ROM and lower extremity flexibility variables ($\alpha = 0.05$).

Results: ER mean value was significantly greater, and IR mean value significantly less, in the dominant arm. TRM mean values were not significantly different bilaterally. Sit-and-reach results were strongly correlated with TRM and ER of the dominant arm.

Conclusions: There was a significant shift in TRM toward ER in collegiate baseball players. Lower quarter flexibility was strongly correlated with dominant arm ER and total rotation ROM but not in the nondominant arm.

Clinical Relevance: The sit-and-reach test may be useful to identify a pitcher's potential to achieve an appropriate amount of trunk forward tilt. This may maximize the lag effect necessary to achieve maximum ER of the dominant arm and increased ball velocity.

Keywords: pitching; throwing shoulder; range of motion; flexibility

The throwing motion is a kinetic chain event that involves the neuromuscular coordination and sequencing of body segments that results in the transfer of energy from the lower extremities to the hips, pelvis, trunk, shoulder girdle, arm, hand, and finally, the ball.[9] Effective throwing mechanics are a result of a pitcher's ability to efficiently execute this progressive sequence of movements.[1] The biomechanics of pitching have been studied extensively.[1,4,7,8,11,16,20] Success in reaching elite levels of baseball competition can often be attributed to a player's ability to maximize performance and minimize injury. Because of the complex nature of the pitching motion, upper extremity function may be intimately related to lower extremity mechanics.

Ball velocity is an important measure of performance for baseball pitchers, and studies have been performed investigating the related factors.[4,6,16] One variable that appears to be linked to velocity is trunk forward tilt (TFT). Stodden et al[16] reported that ball velocity increased as TFT at release increased. As an individual pitcher throws faster, pelvis and upper torso angular velocities increase, and so does TFT. A lag effect (Figure 1) between horizontal abduction of the humerus and subsequent external rotation (ER) in relation to the trunk is induced by this combination of movements. A motion analysis study showed that a loss of TFT may be related to muscular fatigue with the pitching motion and decreased ball velocity.[4] Fatigued collegiate baseball pitchers during the final 2 innings

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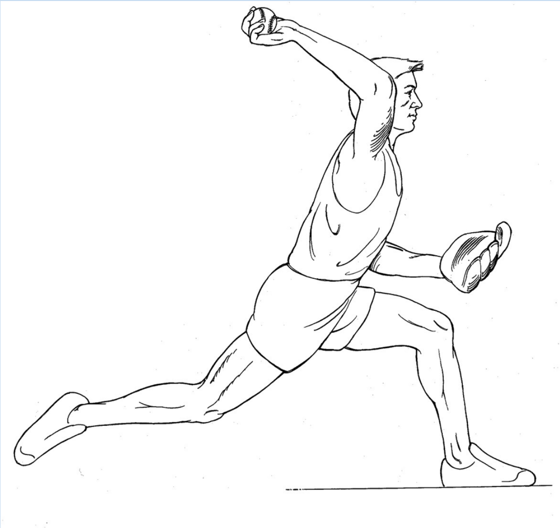

Figure 1. The lag effect between horizontal abduction of the humerus and subsequent external rotation in relation to the trunk is induced by a combination of movements.

Figure 2. Measurement of external rotation range of motion with scapular stabilization.

of a simulated baseball game demonstrated a significant decrease in ball velocity with the trunk remaining significantly closer to the vertical position compared with that in the initial 2 innings.[6] These studies suggest a relationship between TFT and ball velocity with the pitching motion; however, the exact mechanism has not been identified. Functionally, the ability to bend forward at the trunk can be related to hamstring flexibility and trunk mobility. The sit-and-reach test is utilized as an indicator of trunk mobility and hamstring flexibility and consequently may be related to shoulder motion in pitchers.[18]

The link between lower and upper extremity mechanics is evident during the various phases of the pitching motion. As momentum is transferred from the lower extremities, through the trunk, to the point of ball release, the throwing arm lags into maximum ER as the trunk rapidly rotates forward.[9] The pitching motion requires ER to allow for appropriate transfer of momentum during the arm-cocking phase[9]: ER of 108.9° ± 9.0°.[3] In overhead athletes, the dominant arm often exhibits significantly more ER and significantly less internal rotation (IR) relative to the nonthrowing shoulder. These differences may be related to osseous changes (humeral and glenoid retroversion), soft tissue adaptations (glenohumeral ligament laxity), or a combination of both.[2,5,15,17] Nonetheless, there is evidence of increased range of motion in dominant arm ER and total rotation motion (TRM) for effective pitching mechanics.[2,3,5,10,14,16,17] Clinically, excessive ER and limited IR have been found in painful throwing shoulders,[17] and increased TRM has been linked to instability-related injuries.[19,21] As a result, the literature supports assessment of glenohumeral TRM in addition to ER and IR.[5]

The cause of injury and dysfunction of the shoulder complex in individuals performing repetitive overhead motion athletic activities (ie, baseball players) is often multifactorial. While much shoulder pathology is related to the strength and stability of the shoulder girdle, the relationship between bilateral shoulder range of motion and lower quarter flexibility is unknown. It was hypothesized that glenohumeral rotational range of motion is correlated with lower quarter flexibility in collegiate-level baseball players; as lower quarter flexibility increases, so will glenohumeral rotational range of motion.

METHODS

Following institutional review board approval and collection of informed consent, a convenience sample of National Collegiate Athletic Association Division I baseball players from 2 local universities was utilized for a longitudinal study examining a multifactorial assessment of collegiate-level overhead athletes. Forty-two participants from 2 data collection periods were selected for this analysis. They were primarily right-hand dominant (n = 36 right, n = 6 left).

For assessment of ER, participants lay supine with their shoulder and elbow in 90° of abduction and flexion and with the humerus supported by a towel to ensure neutral horizontal positioning.[12] From the starting position (0° of rotation), the examiner passively rotated the shoulder while stabilizing the scapula (Figure 2). End range of ER was defined as cessation of rotation or when scapular movement was appreciated. IR was measured with techniques similar to those for ER (Figure 3).[5,12,21] At end range, a standard goniometer was positioned with the axis over the olecranon process and with the stationary arm perpendicular to the floor. Intrarater reliability for this technique has been reported with intraclass correlation coefficients ranging between 0.87 and 0.99.[12] Intraclass correlation coefficient values for intertester reliability range from 0.84 to 0.90.[12] The distal arm was then positioned in alignment with the ulnar styloid process. The angle created between the stationary goniometer arm and distal goniometer arm was recorded. Three ER and IR measurements were taken

Figure 3. Measurement of internal rotation range of motion with scapular stabilization.

Figure 4. Sit and reach test starting position.

and averaged for each limb. TRM was calculated as the sum of the average ER and IR for each arm.

Flexibility was assessed with a sit-and-reach box (Acuflex1, Novel Products Inc, Rockton, Illinois). Participants sat on the floor with legs extended and shoes off. Their feet were placed with the soles flat against the box, shoulder width apart (Figure 4). With hands on top of each other and palms facing down, the participants reached forward along the measuring line as far as possible while maintaining knee extension (Figure 5). Three measurements were taken and the average calculated.

STATISTICAL ANALYSIS

Paired *t* tests were used to test for differences between the dominant and nondominant arms for ER, IR, and TRM. Pearson product-moment correlation coefficients were used to examine the relationships between shoulder range of motion and lower extremity flexibility variables. An α level of 0.05 was set before all analyses.

Figure 5. Sit-and-reach test finish position.

Table 1. Mean range of motion by dominant arm.

	Dominant	Nondominant
Internal rotation	48.0	60.7*
External rotation	98.9	84.9*
Total motion	146.9	145.6

*$P \leq 0.05$ and **$P \leq 0.01$.

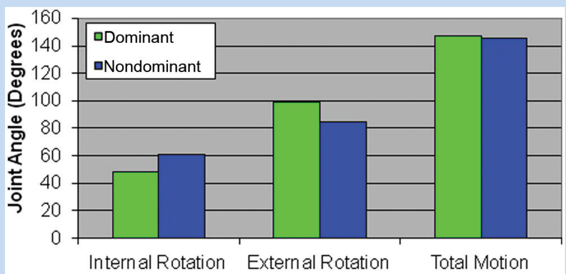

Figure 6. Range of motion by dominant arm. Internal rotation of the dominant arm (47.98 ± 9.88) was significantly less than internal rotation of the nondominant arm (60.69 ± 8.27). External rotation of the dominant arm (98.92 ± 17.68) was significantly different than that of the nondominant arm (84.94 ± 10.79). Total rotation motion was not significantly different between arms.

RESULTS

Forty-two participants were studied: mean height = 72.88 in. (1.85 m), mean weight = 195.6 lb (88.72 kg). IR of the dominant arm (47.98 ± 9.88) was significantly less than that of the nondominant arm (60.69 ± 8.27). ER of the dominant arm (98.92 ± 17.68) was significantly different from that of the nondominant arm (84.94 ± 10.79). TRM was not significantly

Table 2. Correlations[a]

	SAR	ER_{DOM}	ER_{NON}	IR_{DOM}	IR_{NON}	TRM_{DOM}
ER_{DOM}	.752**					
ER_{NON}	.272	.493**				
IR_{DOM}	.287	.158	.175**			
IR_{NON}	.024	.056	–.102	.372*		
TRM_{DOM}	.752**	.892**	.485**	.587**	.217	
TRM_{NON}	.245	.448**	.770**	.385*	.556**	.544**

[a]SAR, sit-and-reach test; ER, external rotation; IR, internal rotation; TRM, total rotation motion; DOM, dominant arm; NON, nondominant arm.
*$P < 0.05$. **$P < 0.01$.

different between arms (Table 1, Figure 6). TRM_{DOM} was strongly correlated with ER_{DOM} and moderately correlated with ER_{NON}, IR_{DOM}, and TRM_{NON} ($r = 0.89$, $r = 0.49$, $r = 0.59$, $r = 0.54$, respectively; $P \leq 0.01$). ER_{DOM} was not significantly correlated with IR_{DOM} ($r = 0.16$, $P = 0.32$). Sit-and-reach was strongly correlated with TRM_{DOM} and ER_{DOM} ($r = 0.75$ and $r = 0.75$; $P \leq 0.01$) and not correlated with ER_{NON} ($r = 0.27$, $P = 0.09$) (Table 2). Exclusion of participants occurred if they had been diagnosed with a medical condition limiting safe participation in the study or they had been treated for shoulder dysfunction in the previous year. Exclusion was made for 1 player receiving treatment for a lumbar disc herniation; another exclusion was made for incomplete data.

DISCUSSION

The baseball pitching motion is a kinetic chain activity that requires an efficient transfer of momentum from the lower extremities to the moment of ball release. The current study demonstrates that for collegiate-level baseball players, TRM_{DOM} was biased toward ER. This supports findings in the current literature.[2,3,5,10,13-15,17] TRM of the dominant and nondominant arms was not significantly different despite significant differences in ER and IR. In other words, overall TRM remained unchanged bilaterally (TRM_{DOM} = 146.9, TRM_{NON} = 145.6). It was also noted that flexibility, as assessed with the sit-and-reach test, was strongly correlated with both TRM_{DOM} and ER_{DOM}.

Sit-and-Reach and Global Flexibility

Examining the influence of lower extremity mechanics on the upper extremity in baseball players is important because significant forces generated by the lower quarter move through the entire kinetic chain. We hypothesized that increased lower extremity and trunk flexibility, identified with the sit-and-reach test, may be indicative of an athlete's potential for soft tissue extensibility in the upper extremity.

TFT and Velocity

The direct relationship between TFT and ball velocity is known: As TFT increases, so does ball velocity and vice versa.[4,6,16] Shoulder abduction during arm acceleration and TFT at ball release were associated with increased ball velocity.[16] Pitchers who threw faster demonstrated increased pelvis and upper torso angular velocities with an increase in TFT.[16] As a result, a lag effect was created inducing horizontal abduction and ER of the humerus as the trunk moved forward.[16] As TFT increased, so did ball velocity.

The relationship between age and baseball pitching kinematics in professional baseball pitchers found that the inverse was also true.[4] Older pitchers produced less shoulder IR during the arm-cocking phase, more lead knee flexion, and less TFT at ball release. The ability of the trunk to rotate forward may relate to a more efficient transfer of energy through the trunk to the throwing arm. A loss of TFT may be related to muscular fatigue, the pitching motion, and decreased ball velocity.[4]

Escamilla et al reported similar findings in collegiate baseball pitchers: a significant decrease in ball velocity with the trunk closer to the vertical position (decreased TFT) in the final 2 innings of a simulated baseball game.[6] The current study suggests that a link may exist among lower extremity flexibility, trunk mobility, and maximum ER of the throwing arm. Individuals who have the dynamic lower extremity flexibility to allow for an optimal TFT are more efficient in transferring forces from the lower extremity to the upper extremity and, eventually, the ball.

The relationship between trunk and lower extremity mobility and upper extremity mechanics becomes increasingly evident during the arm-cocking phase, as the lower half of the body moves forward while the throwing arm rotates backward. During this phase, momentum is transferred through the legs, hips, and trunk as the arms move apart. As the trunk rapidly bends forward, the throwing arm "lags" into maximum shoulder ER.[9] The arms move apart: the throwing arm moves backward as the front leg strides toward the target, causing the upper and lower body to "stretch out." This movement creates elastic energy that is transferred to the throwing arm during the acceleration phase. Meanwhile, the trunk continues to tilt forward to the point of ball release during the delivery (Figures 7 and 8).[9]

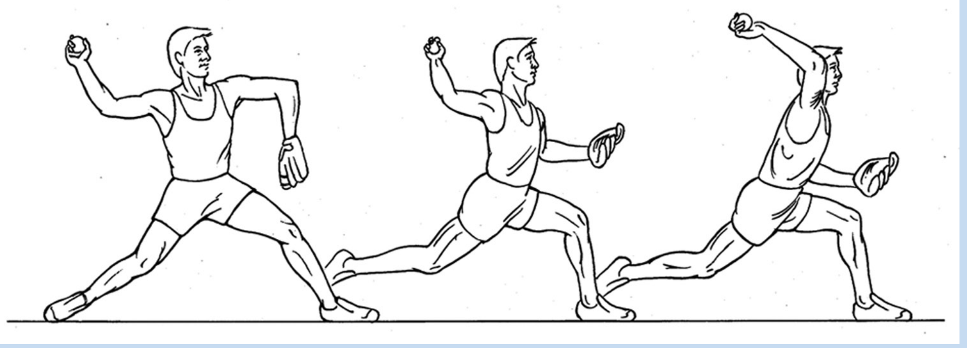

Figure 7. Arm acceleration.

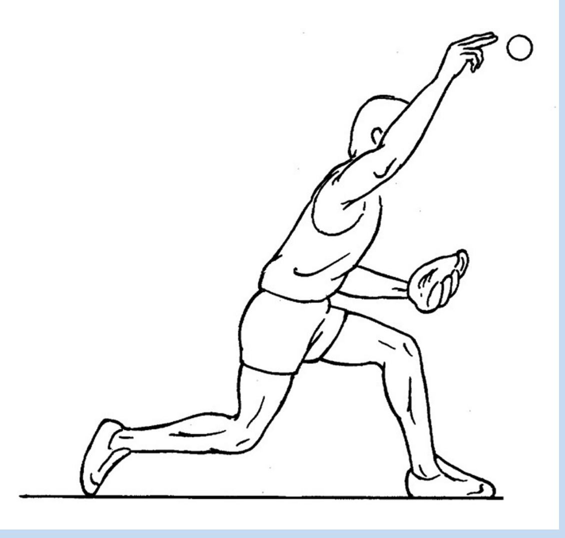

Figure 8. Ball release.

The pitching motion requires ER to allow for optimal transfer of momentum during the arm-cocking phase. While discussion continues regarding whether increased ER in overhead athletes is due to soft tissue or bony adaptations, most agree that both factors contribute.[2,3,5,10,13,14,17] Pitching performance and pitch velocity are related to maximum ER,[2] which may be upward of 165°.[9] Downar and Sauers reported ER of 108.9° ± 9.0°.[3] Differences in these measures are related to difficulties in separating motion at the glenohumeral and scapulothoracic joints and the thoracic spine.

The sit-and-reach test and TRM_{DOM} and ER_{DOM} may be linked in the following manner: The test is indicative of hamstring flexibility and trunk mobility, which allow for appropriate TFT during the pitching motion. Effective TFT may allow for a lag effect inducing upper and lower body separation. The lag effect leads to humeral horizontal abduction and maximum ER. As a result, this process may increase elastic energy that can be transferred to the ball. The sit-and-reach test may indicate the athlete's soft tissue extensibility potential. Likewise, a simple sit-and-reach assessment may identify throwers at risk for shoulder dysfunction prior to injury.

Limitations of this study include no sample size estimate, lack of reproducibility of testing, and a modest sample size and age range. Sit-and-reach reliability and validity can be confounded by spinal and upper extremity flexibility. Regarding personal characteristics, the participants had similar backgrounds prior to their collegiate experience, although each player's history of precollegiate participation was not documented. Finally, the participants were primarily right-hand dominant.

CONCLUSIONS

This study demonstrated a relationship between dominant arm rotational range of motion and the sit-and-reach test. This test may identify a pitcher's potential for TFT to maximize the lag effect necessary to achieve maximum ER of the dominant arm and increased ball velocity.

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