

ORIGINAL RESEARCH

LOWER EXTREMITY BALANCE IS IMPROVED AT TIME OF RETURN TO THROWING IN BASEBALL PLAYERS AFTER AN ULNAR COLLATERAL LIGAMENT RECONSTRUCTION WHEN COMPARED TO PRE-OPERATIVE MEASUREMENTS

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ABSTRACT

Background/Purpose: Lower extremity balance deficits have been shown to lead to altered kinematics and increased injury risk in lower extremity athletes. The purpose of this study was to compare lower extremity balance in baseball players with an ulnar collateral ligament (UCL) tear pre-operatively and post-operatively at the beginning of the pre-return to throwing program stage of rehabilitation (3 months).

Methods: Thirty-three competitive high school and collegiate male baseball players (18.5 ± 3.2) with a diagnosed UCL tear volunteered for the study. Of the 33 baseball players 29 were pitchers, 1 was a catcher, and 3 were infielders. Participants were seen pre-operatively and at 3 months post operatively. This 3 month point was associated with a follow-up visit to the orthopedic surgeon and subsequent release to begin the pre-return to throwing mark for baseball players following their surgery. Following surgery, each participant followed a standard UCL protocol which included focused lower extremity balance and neuromuscular control exercises. Participants were tested for single leg balance using the Y-Balance Test™ – Lower Quadrant (YBT-LQ) on both their lead and stance limbs. YBT-LQ composite scores were calculated for the stance and lead limbs pre- and post-operatively and compared over time. Paired t-tests were used to calculate differences between time 1 and time 2 ($p < 0.05$).

Results: Baseball players with diagnosed UCL tears demonstrated significant balance deficits on their stance ($p < .001$) and lead ($p = .009$) limbs prior to surgery compared to balance measures at the 3-month follow up (Stance Pre-Op = $89.4 \pm 7.5\%$; Stance 3 Month = $94.9 \pm 9.5\%$) (Lead Pre-Op = $90.2 \pm 6.7\%$; Lead 3 Month = $93.6 \pm 7.2\%$).

Conclusion: Based on the results of this study, lower extremity balance is altered in baseball players with UCL tears prior to surgery. Statistically significant improvements were seen and balance measures improved at the time of return to throwing.

Level of Evidence: Level 2b

Keywords: Balance, baseball, ulnar collateral ligament

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INTRODUCTION

Ulnar collateral ligament (UCL) injuries and reconstructions have become increasingly common in the overhead athlete. The reported incidence of UCL injuries in high school baseball players has risen significantly, with the year round nature of the sport being suggested as a contributing factor.¹ Additionally, 5% of youth pitchers sustained serious upper extremity injury (requiring shoulder or elbow surgery or ended career) over a 10-year span with pitching greater than 100 innings per year significantly increasing the risk.² As the number of athletes playing baseball and the number of innings played per year increases, the need to better understand these injuries also increases.

Post-operative rehabilitation of UCL reconstruction often includes elbow and shoulder range of motion (ROM), strengthening of the rotator cuff and posterior shoulder musculature, and correction of faulty scapular mechanics.³⁻⁶ The athletes are progressed from the ROM phase (early) to the strengthening phase (middle) and eventually to the return to throwing phase (late). In our center, the phase just prior to returning to throwing is referred to as the “pre-return to throwing” phase. In this phase, plyometric activities are begun to prepare the athlete to accept the high forces at the shoulder and elbow that accompany throwing. With most post-operative UCL protocols, this phase typically begins around 3 months post-surgery, with the anticipation of beginning a throwing program at four months post surgically.^{5,6} Because throwing is a whole body movement that requires balance, coordination, and efficient energy transfer, high valgus forces at the elbow are likely not the sole contributor to UCL injuries. The true etiology is likely multifactorial and may be related to a break down along the kinetic chain.^{7,8}

Balance has previously been defined as the dynamics of body posture to prevent falling and is affected by the internal forces acting on the body.⁹ This may involve movement around an established base of support while performing tasks, such as standing on one limb while reaching with another segment, without disrupting the established base of support.^{7,10} Alterations in trunk and lower extremity control during the throwing motion have been hypothesized to alter the location of the shoulder and elbow,

potentially resulting in increased stress across both joints. Recently published data suggests that lower extremity balance may be associated with UCL tears in the overhead athlete.¹¹ High school and college baseball players with a diagnosed UCL tear scored significantly lower on the Y-Balance Test™ – Lower Quadrant (YBT-LQ) on their stance ($p = 0.001$) and lead ($p < 0.001$) limbs when measured pre-operatively as compared to their non-injured cohort.¹¹ Although this recently published data does not explain a direct cause and effect for these injuries, the results suggest a relationship between UCL tears and deficits in lower extremity balance. While the importance of balance has been studied extensively in lower extremity rehabilitation,¹²⁻¹⁴ there is limited evidence to support this in upper extremity injuries, specifically in baseball players.¹¹

Therefore, the purpose of this study is to examine the pre-surgical and 3 month post-operative measurements of lower extremity balance in baseball players who have undergone a UCL reconstruction.

METHODS

Participants

Thirty-three male competitive high school and collegiate baseball players from across the United States (average age = 18.6 ± 2.9) volunteered to participate in this study. Of the 33 participants, 29 were pitchers, 1 was a catcher, and 3 were infielders. Participants had an average of 13.2 ± 2.2 years of playing experience. All subjects gave informed consent to participate and the rights of each person were protected. The Institutional Review Board of Texas Health Resources approved the research procedures. Table 1 summarizes the demographic characteristics of the participants.

Table 1. Characteristics of baseball players with UCL tears ($n = 33$)

Age	18.5 ± 3.2 (range= 15-25) years
Throwing arm	
Right	28
Left	5
Years of Experience	13.2 ± 2.2 (range= 7-17) years
Position	
Pitcher	29
Catcher	1
Infielder	3
Level of play	
College	20
High school	13

The diagnosis of UCL injury was made based upon clinical examination by a fellowship-trained, board-certified orthopedic surgeon (JEC) and was confirmed via results of magnetic resonance imaging (MRI).

Subjects were considered for study participation if they were a baseball player between the ages of 15 and 25. Inclusion criteria for the study included 1) the individual's ability to throw was affected by the injury, 2) the individual was unable to continue to participate in baseball at the level prior to UCL tear, 3) clinical exam results were positive for UCL tear, 4) confirmation of UCL tear was made via MRI, and 5) the individual was attempting to return to their sport at a competitive level.

Exclusion criteria included 1) a previous UCL reconstruction that failed, 2) previous shoulder injury or surgery (to include labral tear or rotator cuff involvement), and 3) if the patient did not plan to return to baseball at a competitive level following treatment. Patients were enrolled into the study by an investigator in the outpatient sports physical therapy facility once screened for the inclusion and exclusion criteria. Once the patient offered consent, objective measurements of YBT-LQ were taken. Patients were seen at initial evaluation prior to surgery, which occurred at an average of 5 weeks from injury onset. Patients were seen again for follow up measurements at 3 months post-surgery.

Testing

The YBT-LQ was utilized as a measure of trunk and lower extremity function. The YBT-LQ assesses ROM, strength, and neuromuscular control of the lower extremity and was chosen to assess the participants' lower limb balance as numerous prior studies have demonstrated its utility as a clinical test to assess for lower limb balance deficits in the athletic population.^{12,13,15,16} Previous authors have described deficits in balance scores as they relate to lower extremity injury risk.¹² Additionally, the YBT-LQ has been used previously to assess balance deficits in the UCL injured athlete.¹¹ Measurements were taken in 3 distinct directions of anterior (ANT), posteromedial (PM) and posterolateral (PL) on both the stance and lead limbs. The stance limb was determined as the limb on which a thrower begins the throwing motion on (same side as the dominant arm) thus identifying the opposite limb as the lead limb. The participants

were instructed in the YBT-LQ protocol using a combination of verbal cues and demonstration.¹⁵ The Y Balance Test Kit™ was utilized throughout the study. All participants wore shoes during testing and began on their stance limbs. The participants were asked to perform single limb stance on the extremity while reaching outside their base of support to push a reach indicator box along the measurement pipe.¹⁵ Elevation of the heel, toe or loss of balance resulting in a stepping strategy was recorded as a trial error indicating the trial should then be repeated. Subjects were allowed at least 4 practice trials in the ANT, PM and PL directions prior to recording the best of 3 formal trials in each plane. Three trials were completed on the stance limb in the ANT (Figure 1) direction followed by 3 trials completed on the lead limb.¹⁵ This protocol was then replicated in the PM (Figure 2) and PL (Figure 3) directions. The maximal reach distance was recorded at the place where the most distal part of the foot reached based on the measurement pipe.



Figure 1. Y Balance Test™ Anterior Reach.

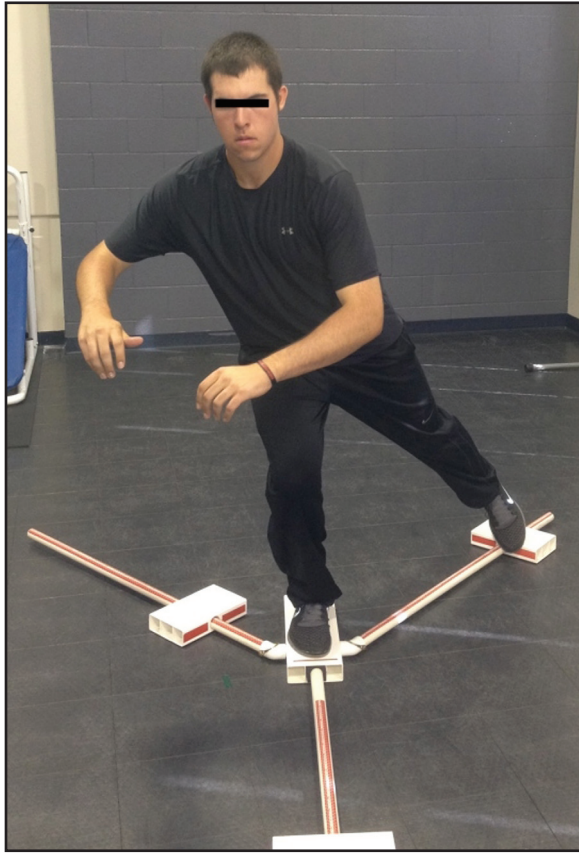


Figure 2. *Y Balance Test™ Posterior Medial Reach.*



Figure 3. *Y Balance Test™ Posterior Lateral Reach.*

The composite scores were calculated by adding the reach distances of ANT, PM, and PL, dividing by three times the participant's leg length, and then multiplying by 100 to obtain a percentage.^{12,15} The leg

length was determined using the distance between the most prominent portion of the greater trochanter and the floor while the individual was in a standing position. Composite YBT-LQ scores of the stance and lead limbs were computed for each of the athletes in this study.

Inter-rater reliability was determined prior to the initiation of this study using an Intraclass correlation coefficient (ICC). Reliability of the measurements for the anterior (ICC3,1 = 0.86; SEM, 3.3 cm), posteromedial (ICC3,1 = 0.99; SEM, 1.7 cm), and posterolateral (ICC3,1 = 0.95; SEM, 2.7 cm) directions for the testers participating in the study was considered to be acceptable. These values are similar to previously published data on intrarater (ICC3,1 = 0.91) and inter-rater (ICC2,1 = 0.99) reliability of composite scores for this test.^{15,17} Validity of the test has been previously shown in relation to hip kinematics and gluteal muscle activation.¹⁷

Treatment

Treatment of each subject was guided by a standard UCL post-operative protocol (Appendix A) developed in conjunction with the orthopedic surgeon (JEC). The protocol includes an early emphasis on ROM recovery, progressing to integrated strengthening of the shoulder and elbow musculature, and finally to upper body plyometrics and throwing. Included within this protocol are instructions to incorporate lower extremity strengthening, neuromuscular control, and balance exercises, beginning as early as 4-6 weeks post operatively. Balance exercises typically included in this phase of rehabilitation were designed to challenge the stability of the athlete while requiring them to demonstrate adequate trunk control throughout the given motion. The single leg stride (Figure 4 A, B) is an exercise used during this phase. During this exercise the athlete stands on their stance limb and maximally reaches into the frontal plane with their lead limb. They are instructed to reach as far as possible and return to the starting position without placing the lead limb onto the ground or without losing balance. A second exercise that is implemented during this phase includes single limb transverse plane core reaches (Figure 5 A, B). During this exercise the athlete stands in a single limb stance with their back to a wall. They are instructed to move into a combination of hip

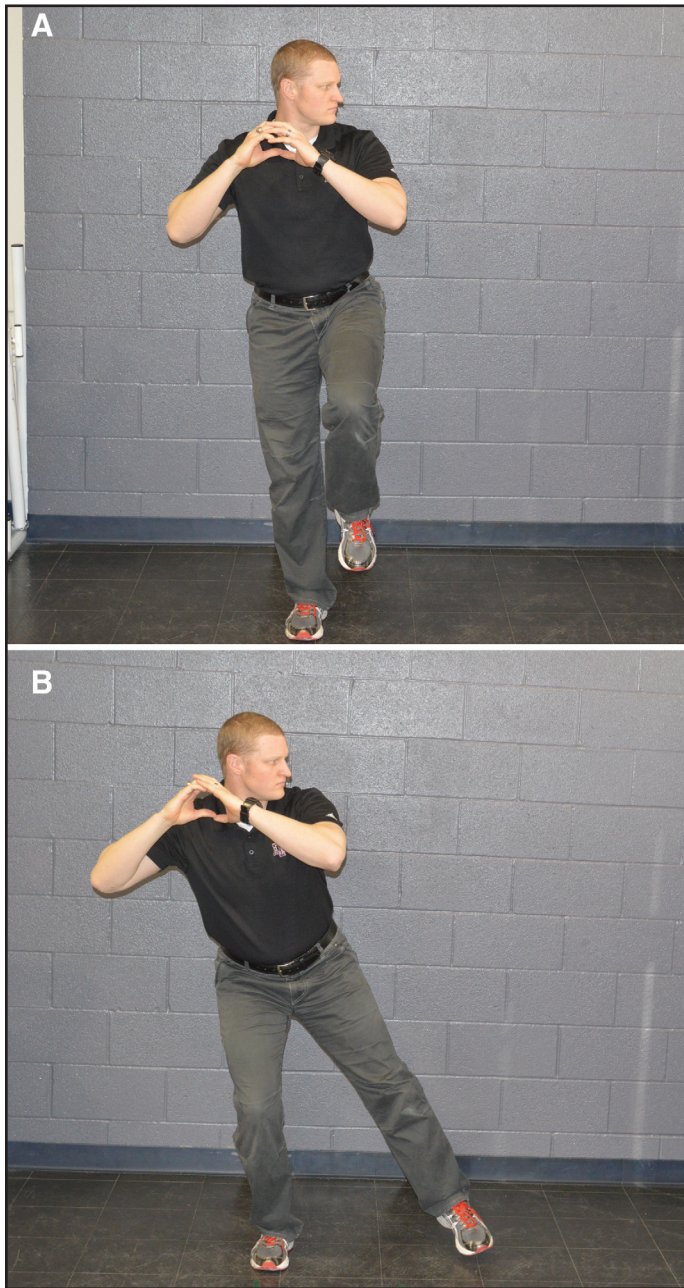


Figure 4. Single leg stride exercise, important to the motion of pitching. A = starting position, B = finish position. The athlete starts in a single limb stance. They are then instructed to reach out with their lead limb while maintaining their balance on their stance limb.

and trunk extension with rotation until their shoulder contacts the wall. Participants are cued to perform this exercise in a slow and controlled manner and to increase the distance from the wall as control improves. Additional exercises that can be incorporated include the single limb lawnmower and body blade exercises (Figure 6 A, B), and the single limb wall ball exercise (Figure 7).

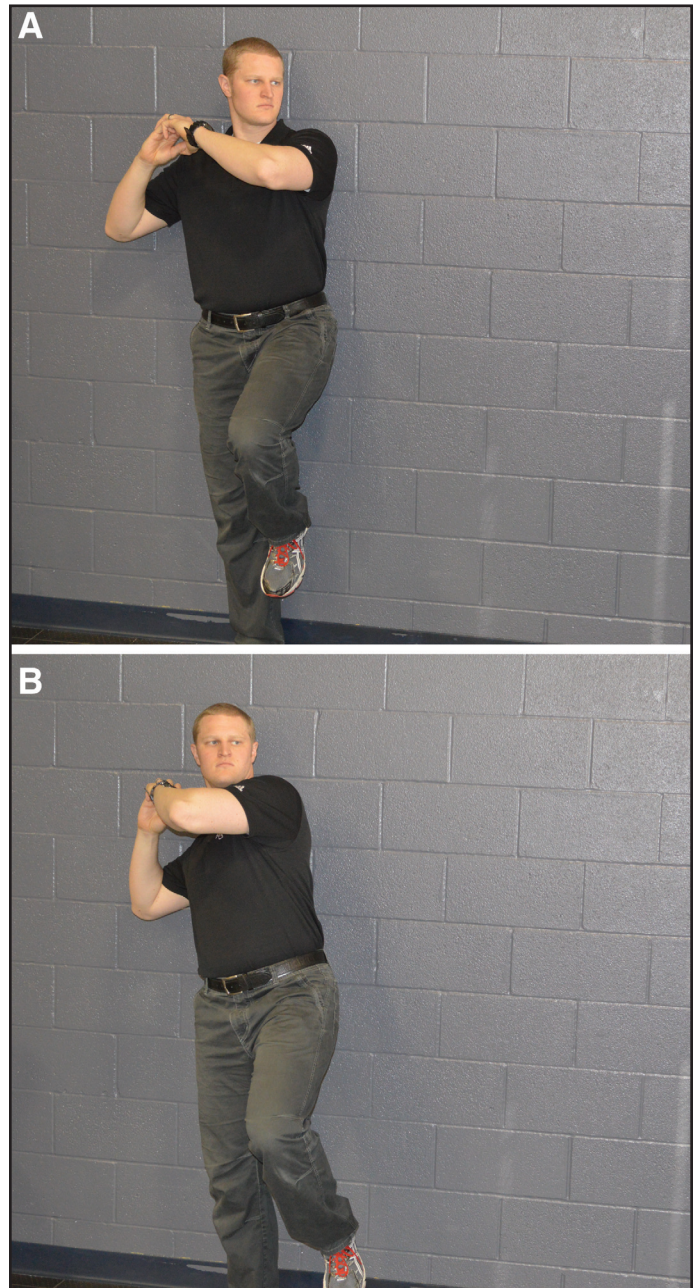


Figure 5. Single leg core reaches, A = starting position, B = finish position. The athlete stands with their back to the wall on a single limb. The athlete is then instructed to move into trunk extension and rotation while maintaining single limb control and attempt to tap their shoulder to the wall. The athlete is instructed to tap their right and left shoulders to the wall in an alternating fashion.

DATA ANALYSIS

Paired T-Tests were used to determine significant mean differences between the pre- and post-test results of YBFLQ composite scores for stance and lead limbs at both points in time with significance set at $p < 0.05$.

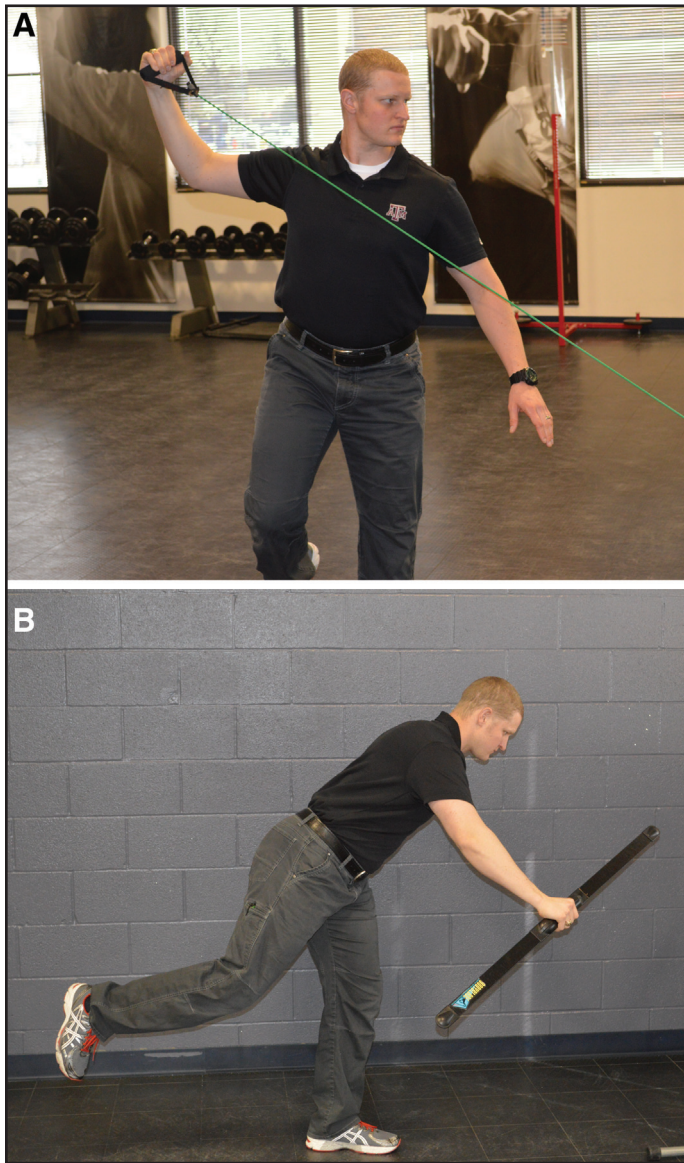


Figure 6. Single limb UE exercises, A = “lawnmower” motion, B = Body Blade™ throwing motion. These exercises are designed to mimic the throwing motion with the UE while maintaining single limb control throughout the motion.

RESULTS

Baseball players with a diagnosed UCL tear demonstrated diminished stance ($89.4 \pm 7.5\%$) and lead ($90.2 \pm 6.7\%$) limb balance, as measured by the YBT-LQ at time of injury. The YBT-LQ composite balance scores on both the stance and lead limbs fall below previously published normative data for lower extremity injury risk ($\leq 94\%$)¹² and are in line with earlier YBT-LQ composite scores in baseball players with a UCL tear (stance = $88.2 \pm 7.9\%$, lead = $89.1 \pm 6.7\%$).¹¹ At 3 month post-operative follow up, baseball players with a diagnosed UCL tear and a subsequent



Figure 7. Single Limb Wall Ball exercise: The athlete stands with their involved UE nearest the wall. Their arm is placed in the 90/90 position to mimic the athletes arm slot during throwing. The athlete is then instructed to stand on their stance limb and perform repeated ball bounces on the wall while maintaining their balance.

repair demonstrated a significant improvement in lower extremity balance on both their stance ($94.9 \pm 9.5\%$) and lead ($93.6 \pm 7.2\%$) limbs compared to their pre-operative measurements. Table 2 outlines the lower limb balance findings at time 1 (pre-operative) and time 2 (three months post operative). Baseball players with diagnosed UCL tears demonstrated significant balance improvements on their stance ($p = .001$) and lead ($p = .009$) limbs after surgery compared to balance measures taken preoperatively.

DISCUSSION

Improvements were found in lower extremity balance on both the stance and lead limbs of baseball players at the three month mark following UCL reconstruction. These individuals demonstrated significant improvements in lower extremity balance

Table 2. Y Balance Test-Lower Quarter™ composite scores, normalized by leg length.

	Pre-surgical	3- month follow up	P value
Y Balance Test™ – composite score normalized for stance leg	89.4±7.5%	94.9±9.5%	.001*
Y balance test™ – composite lead leg	90.2±6.7%	93.6±7.2%	.009*

*Denotes statistically significant difference, $p < 0.05$

on their stance and lead limbs at the three-month follow up compared to their pre-operative measurements. These results are consistent with recent published data examining lower extremity balance deficits in baseball players with UCL tears.¹¹ High school and college baseball players with a diagnosed UCL tear were compared to age- and position-matched controls and were found to have significant balance deficits in both their stance (7.2%) and lead (6.7%) lower extremities at the time of initial diagnosis. Although both studies found balance deficits at the time of UCL injury and prior to surgical reconstruction, it is difficult to determine whether this deficit played a role in predisposing the athlete to injury or was a result of the injury. Both studies are observational, and as such no cause and effect relationship can be stated. Previous research does indicate that a deficiency in balance can predict lower extremity injury in basketball players.¹² However, to the authors' knowledge, there are no other studies that directly examine lower extremity balance deficits as they relate to upper extremity injury risk.

While lower extremity balance deficits were present prior to surgery, significant improvements were made in both the stance and lead limbs by the time the athletes began their pre-return to throwing phase (3 months). This finding could have significant implications for rehabilitation and safe progression for return to throwing. Because this study is observational in nature and did not involve a controlled intervention or control group, it is not possible to attribute the lower extremity balance improvements in the current study to a specific treatment effect. However, there are numerous studies examining balance deficits and treatment in lower extremity athletes.^{16,18} Previous research in female soccer players demonstrated improvements in the Star Excursion Balance Test (SEBT) following a neuromuscular training program.¹⁸ The authors of that previous study concluded that neuromuscular training that focused on core stability and lower extremity strength significantly improved balance scores. Improvements in neuromuscular control measured by the SEBT have also been shown in individuals with chronic ankle sprains following neuromuscular training.^{14,19}

While the previous studies all demonstrate the positive effect of neuromuscular training on balance measures, none of the studies examined the effects of neuromuscular training in the overhead athletic

population. In the aforementioned studies female soccer¹⁸ and basketball¹² athletes underwent lower extremity neuromuscular training for 6 and 8 weeks respectively. In both cases a significant improvement in performance was reported. In the present study, initial and follow-up measurements were taken 12 weeks apart, allowing a significantly longer training period than reported in past studies. While the observational design of the current study limits the ability to show a cause and effect relationships, it is possible that waiting 12 weeks between measurements allowed adequate training to take place. A systematic review by Zech et al²⁰ reported that balance training on stable or unstable platforms with or without recurrent destabilization of 6 to 12 weeks, improved neuromuscular control better than training of only 4 weeks, indicating that the longer training duration in the present study may have contributed to the improvements in balance. Similarly, both Zech et al²⁰ and a second systematic review by Thacker et al²¹ reported that individuals who participate in a neuromuscular training program demonstrate significantly decreased injury risk compared to controls. The summary of these findings suggests that participation in a neuromuscular training program, such as the one implemented in the current study may help to improve balance measures in overhead athletes.

What these balance deficits mean at this point is yet to be determined. This can be attributed to a lack of research on balance deficits in throwers, in addition to an incomplete understanding of the kinetic chain effects on the upper extremity during throwing. The effects of lower extremity biomechanics and ground reaction forces (GRF) on pitching have previously been studied in relation to injury prevention and performance.²²⁻²⁵ Additionally, authors of clinical commentaries have attempted to address this void in the literature. Kibler and Chandler²⁶ described how a 20% decrease in kinetic energy delivered from the hip and trunk to the arm required a 34% increase in the rotational velocity of the shoulder to impart the same amount of force to the hand in tennis players. Likewise, the pitching motion has been defined as an integrated motion of the entire body that culminates with rapid motion of the upper extremity.²⁷

While the above explanations are only hypotheses and have yet to be supported by research, the role of the

kinetic chain in the throwing motion and the impact that it could potentially have on injury and injury prevention is beginning to be recognized. This role is evident in a clinical commentary in which the authors hypothesized that distant physiological and biomechanical factors play an important role in generating forces, motions and loads experienced at the elbow.⁷ The current hypothesis seems to suggest that lower extremity force generation may play a significant role in attenuating stress across the upper extremity. At this time, these are simply hypotheses and more research is needed to further understand how the role of lower extremity balance, neuromuscular control and the kinetic chain affects the throwing motion.

A major limitation of this study is the lack of control of the treatment during the 3-month time period. Protocols were supplied and encouraged to be followed, but tracking compliance by the patient and treating therapist was not performed. Although each patient was given a standardized protocol and instructed in the gradual progression based upon both criteria and time for healing, the authors were unable to specifically control what occurred with treatment progression as each patient returned to his home and underwent physical therapy there. Despite this limitation, significant findings were noted. More research is warranted to examine the role of lower extremity balance and the kinetic chain on the throwing motion to help better understand the rehabilitation considerations following UCL reconstruction in baseball players.

CONCLUSION

The results of this study point to improvements in lower extremity neuromuscular control on both the stance and lead limbs of baseball players at the 3 month mark following UCL reconstruction. No direct correlation can be made in regards to decreased lower extremity neuromuscular control and UCL tears; however, improvements in balance were noted on the stance and lead lower extremities at the time of the pre-return to throwing phase.

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