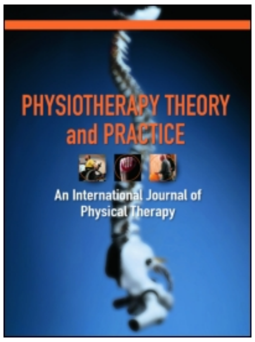

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Longitudinal assessments of strength and dynamic balance from pre-injury baseline to 3 and 4 months after labrum repairs in collegiate athletes

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ABSTRACT

Background: There is a lack of quantitative assessments of athletes' functional strength and dynamic balance following labrum repairs. **Purpose:**To compare the upper extremity strength and dynamic balance among pre-injury baseline and approximately 3 and 4 months after labrum surgeries in collegiate athletes to identify critical values to inform rehabilitation. **Methods:**Fifteen male and one female collegiate athletes between 18 and 22 years old were tested at pre-injury baseline (n = 14) and 2.7 (n = 16) and 3.8 months (n = 12) after labrum surgeries. Strength was assessed using the peak forces produced in a maximal push-up test. Dynamic balance was assessed using the reaching distances in a reaching test. **Results:**The injured side's peak forces significantly decreased from the baseline to the 3-month post-surgery and then significantly increased between the 3-month and 4-month post-surgery assessments but remained significantly less at the 4-month post-surgery compared to the baseline ($p \leq 0.024$; Cohen's $d_z \geq 0.75$). Peak force asymmetries were greater at the 3-month and 4-month post-surgery assessments than the baseline ($p \leq 0.005$; Cohen's $d_z \geq 1.02$). **Conclusion:**With a relatively small sample size, the results support the use of objective functional assessments for rehabilitation and return-to-play decisions among collegiate athletes following labrum repairs.

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SLAP; bankart; labrum surgery; force; range of motion

Introduction

The glenoid labrum is a fibrous rim that surrounds the glenoid cavity to stabilize the glenohumeral joint. Certain labrum injuries may require surgical repairs for specific populations (Dodson and Altchek, 2009). In the general population, the superior labrum from anterior to posterior (SLAP) repairs represent approximately 9.4% of total shoulder surgeries (Weber, Martin, Seiler, and Harrast, 2012). In National Collegiate Athletics Association (NCAA) athletes, SLAP tears and other non-SLAP labrum tears are the two upper extremity injuries mostly requiring surgical treatment (Gil, Goodman, DeFroda, and Owens, 2018). SLAP tears comprise over 17% of shoulder surgeries, while non-SLAP labrum tears are a portion of surgical treatment to shoulder instability that makes up more than 60% of shoulder surgeries (Gil, Goodman, DeFroda, and Owens, 2018).

Sports-related labrum tears are associated with the high-risk repetitive motion and excessive contact force to the shoulder in sports. For example, the most common type (i.e. superior labrum tear and biceps tendon stripping) of SLAP tears is likely caused by repetitive overhead motion (Modarresi, Motamedi, and Jude, 2011). A mechanism of this injury is an abducted and externally rotated shoulder at a high velocity with a strongly activated biceps muscle, which often occurs in baseball pitching, tennis stroking, and volleyball spiking (Modarresi, Motamedi, and Jude, 2011). One frequent non-SLAP tear is the Bankart lesions, mostly occurring as anteroinferior tears of glenoid labrum due to anterior glenohumeral dislocation (McCarty, Ritchie, Gill, and McFarland, 2004). The anterior dislocation likely results from excessive external rotation and abduction of the shoulder, which forces the humerus out of the glenoid socket, damaging anterior structures in the process (Cutts, Prempeh, and Drew, 2009). As such, contact sports and collision sports such as American football and wrestling have an increased risk of anterior glenohumeral dislocations and Bankart lesions (Cho, Hwang, and Rhee, 2006; Mazzocca et al., 2005).

While conservative treatment is an option for patients following labrum tears (Edwards et al., 2010), many athletes who plan to return to their sports receive surgical repairs and perform post-surgery rehabilitation to restore shoulder stability and function. However, residual problems such as pain, decreased range of

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motion, lower activity levels, and elevated re-injury risk still exist (Cohen et al., 2006; Katz et al., 2009; Provencher et al., 2013; Voos et al., 2010; Wang, Liu, Su, and Liu, 2015). In athletes following Type II SLAP repairs, a systematic review reported a general range of 20% to 95% of athletes could return to their previous levels of play (Gorantla, Gill, and Wright, 2010). Another review documented that, on average, 73% of all athletes and 63% of overhead athletes returned to their previous levels of play (Sayde, Cohen, Ciccotti, and Dodson, 2012). In addition to successful surgeries and effective post-surgery rehabilitation, reliable post-surgery assessments and safe return-to-play guidelines are also important for optimizing patients' outcomes (Michener et al., 2018). Return-to-play typically occurs in 4–6 months but may take up to 12 months (McCarty, Ritchie, Gill, and McFarland, 2004). Returning athletes to sports without recovering physical impairments such as joint range of motion and muscle strength might decrease their performance and increase re-injury risk (Makhni et al., 2015). Static measurements suggest shoulder range of motion may improve following SLAP repairs relative to preoperative values (Friel, Karas, Slabaugh, and Cole, 2010; Kim et al., 2012; Provencher et al., 2013). Limited studies have quantified isometric shoulder strength before and after labrum repairs (Boileau et al., 2009; Friel, Karas, Slabaugh, and Cole, 2010). However, most assessments did not include the dynamic perspective of athletic activities, and there was a need to include more functional tests (Michener et al., 2018).

In summary, there is a lack of quantitative assessments of patients' strength and dynamic balance during functional tests following labrum repairs to guide the rehabilitation and return-to-play process. Previous studies have observed decreased shoulder range of motion and isometric strength for the injured side in patients following labrum surgeries, while these deficits could improve over time (Ellenbecker, Sueyoshi, Winters, and Zeman, 2008; Paxinos et al., 2006). However, it is unknown how the injury may affect the performance compared to the pre-injury level. Assessing athletes' performance between pre-injury baseline and post-labrum-surgery assessments is important for understanding the detrimental effects of the injury on physical performance and may help establish critical values to inform rehabilitation. In addition, incorporating dynamics tasks can better simulate the nature of sports tasks to evaluate athletes' functional capacities once they are returned to play.

Therefore, the purpose of this study was to compare the upper extremity strength and dynamic balance performance and bilateral asymmetries among pre-injury baseline and approximately 3 and 4 months after labrum surgeries in NCAA athletes to quantify the effects of the injury on physical performance and identify critical values to inform rehabilitation and return-to-play decisions. Strength and balance were assessed using a maximal push-up test and an upper extremity reaching test. It was hypothesized that the strength and balance performance of the injured side would be the greatest at baseline, the second greatest at 4-month post-surgery, and the least at 3-month post-surgery. Bilateral asymmetries were also hypothesized to be the least at baseline, the second least at 4-month post-surgery, and the greatest at 3-month post-surgery.

Methods

Participants

The current study was a continuation of a previous study in which more than 700 NCAA Division I athletes at one institution performed pre-injury baseline assessments (Dai et al., 2021, 2019). Participants were recruited by their athletic trainers, who were informed of the research opportunity by the researchers. At baseline, participants were 18 years of age or older and fully participated in their sports training. The training volume was approximately 20 hours per week, with 3–5 hours being strength and conditioning training. In the follow-up, 16 athletes had labrum tears and repairs and participated in the current study (Tables 1 and 2). The University of Wyoming Institutional Review Board approved this study. Participants signed informed consent forms for both baseline and post-surgery assessments. Participants signed a medical-release form to allow the researchers to obtain their medical information from their athletic trainers and could choose to ask the researchers to send their testing results to their athletic trainers.

Three athletes had previous labrum surgeries prior to the current surgery. Thirteen athletes' injuries were acute, and the time from the acute injury to the surgery was 1.94 ± 1.87 months. Fourteen athletes performed a pre-injury baseline assessment 9.46 ± 8.73 months prior to the surgery, but two athletes did not perform the baseline assessment. All sixteen athletes performed an assessment approximately 3 months after their surgeries (2.68 ± 0.88 months). Twelve athletes performed another assessment approximately 4 months after the surgery (3.76 ± 0.84 months), but four athletes did not perform the 4-month post-surgery assessment. All athletes were treated with standard rehabilitation programs under the guidance of their team doctors and athletic trainers (Appendix). Athletes started range of motion

Table 1. Participants' sports and surgery information.

Sports	Types of Labrum Surgeries	Numbers of Anchors
Men's American Football	Anterior and posterior Bankart repair	4
Men's American Football	Anterior repair	3
Men's American Football	Anterior repair	4
Men's American Football	Posterior repair	4
Men's American Football	Posterior repair	3
Men's American Football	SLAP and posterior repair	5
Men's American Football	360-degree repair	7
Men's American Football	360-degree repair	6
Men's American Football	360-degree repair	6
Men's American Football	Anterior and posterior inferior repair	4
Men's American Football	Anterior and posterior repair	9
Men's Wrestling	SLAP and Bankart repair	4
Men's Wrestling	Anterior and inferior repair with capsular plication	2
Men's Wrestling	Bankart repair with capsular plication	5
Men's Swimming	Anterior and inferior repair	3
Women's Soccer	SLAP repair	2

SLAP: Superior labrum from anterior to posterior

training for the injured wrist and elbow about 3–5 days after the surgery and passive range of motion training for the injured shoulder about 1–2 weeks after the surgery. The rehabilitation program started with range of motion training and then moved to focus on shoulder strength. Sports specific movements and motor control were introduced around 3 months with a goal to return to sports 4–5 months after the surgery. The current study chose the 3-month post-surgery as athletes typically started high-velocity and change-of-direction movement training around this time. The 4-month post-surgery was chosen as this was an early time point for some athletes to return to play (McCarty, Ritchie, Gill, and McFarland, 2004).

Data Collection

At both baseline and post-surgery assessments, participants performed a maximal push-up test to assess upper extremity strength and an upper extremity reaching test to assess upper extremity balance (Dai et al., 2019). The maximum push-up test on force platforms has been shown as a reliable test for assessing upper extremity strength and bilateral asymmetries in peak force production (Hinshaw, Stephenson, Sha, and Dai, 2018; Wang et al., 2017). The trial-to-trial intraclass correlation (ICC) values were shown to be above 0.97 for the peak pushing forces in non-injured athletes (Dai et al., 2019). The upper extremity reaching test has been demonstrated as a reliable test to evaluate upper extremity mobility and stability and bilateral asymmetries (Gorman, Butler, Plisky, and Kiesel, 2012). The day-to-day ICC values were shown to be above 0.92, and the standard errors of measurement were less than 2.9 cm for the reaching distances in non-injured active adults (Gorman, Butler, Plisky, and Kiesel, 2012). For the push-up test, the participant began with keeping the arms straight and the hands below the shoulders while placing the feet shoulder-width apart (Figure 1). The participant was instructed to lower the shoulders to the height of the elbows and push as hard as possible. For the reaching test, the participant started with keeping the hand of the testing side on the stance plate and feet shoulder-width apart on the ground (Figure 2). The participant used the free hand to push the side of the reaching box in the lateral direction. The participant could bend the elbow of the supporting arm and lean the body to achieve the maximal distance, but the feet must be kept on the ground. If the participant could not maintain balance before coming back to the starting position, the trial will be repeated. Participants performed a minimum of 1 practice and 3 official push-up trials while bilateral vertical ground reaction forces were collected at a sampling frequency of 1,000 Hz using two force platforms (4060–05 or 4060–10; Bertec, Columbus, OH, USA). Participants performed a minimum of 1 practice and 3 official reaching trials for each arm using A Y-balance kit (Move2Perform, Evansville, IN, USA). The arm length was measured from the 7th cervical vertebra to the tip of the longest finger of the right side.

Data Reduction

Vertical ground reaction forces were filtered using a fourth-order, zero-phase-shift Butterworth filter at a low-pass cutoff frequency of 100 Hz. Peak pushing forces for each arm were extracted as the peak forces between the initiation of the push and takeoff (Figure 3). The average of the three push-up trials was used for

Table 2. Means ± standard deviations of demographic information.

	Baseline	3-month post-surgery	4-month post-surgery
Sex (n)	Males (13) and Females (1)	Males (15) and Females (1)	Males (12)
Age (years)	19.3 ± 0.8	20.3 ± 0.9	20.4 ± 0.8
Height (m)	1.83 ± 0.09	1.85 ± 0.08	1.89 ± 0.05
Mass (kg)	92.5 ± 14.8	95.7 ± 16.5	102.0 ± 15.0

Figure 1. The maximal push-up test on two force platforms.

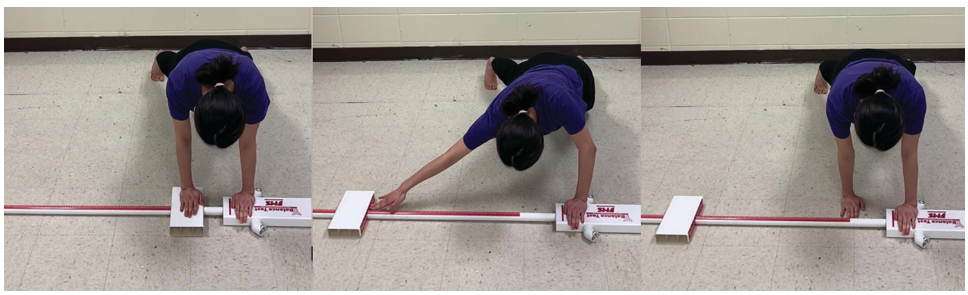

Figure 2. The upper extremity reaching test.

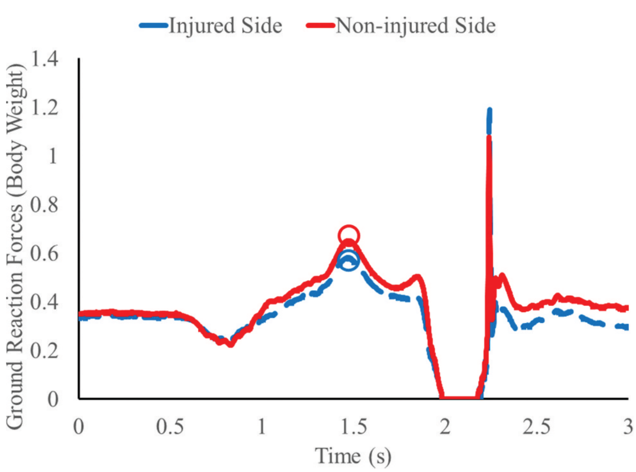

Figure 3. Bilateral ground reaction forces in the push-up test. Peak pushing forces for the non-injured and injured sides are circled.

analyses (Dai et al., 2019). These calculations were performed using subroutines developed in MATLAB 2017b (MathWorks, Inc., Natick, MA, USA). For the reaching test, the longest distance of the three trials was analyzed for each arm (Gorman, Butler, Plisky, and Kiesel, 2012). The bilateral peak forces and reaching distances were normalized to body weight (BW) and arm length, respectively (Dai et al., 2019). The asymmetry index was calculated using the equation: (non-injured side – injured side)/(larger value of the two sides). A positive value indicated greater performance on the non-injure side, and a negative value indicated greater performance on the injured side.

Statistical Analyses

ICC [3, k] values and standard errors of measurements among the three official trials for the peak-pushing forces for the non-injured and injured sides at the three assessments were calculated. These reliability variables were not calculated for the reaching distances because only one trial with the greatest distance was recorded for analysis as suggested by a previous study (Gorman, Butler, Plisky, and Kiesel, 2012). Repeated-measure analyses of variance (ANOVA) were performed for peak forces and reaching distances for the non-injured and injured sides and bilateral asymmetries of peak forces and reaching distances among baseline, 3-months post-surgery, and 4-months post-surgery. Significant ANOVA main effects were followed up with paired t-tests. A type-I error rate was set at 0.05 for statistical significance. Cohen's d_z (< 0.5 = "small," 0.5–0.8 = "medium," and > 0.8 = "large") was calculated to evaluate the effect size of the change between two paired conditions (Cohen, 1988). Cohen's d_z was calculated as the mean of the differences between two conditions divided by the standard deviation of the differences between two conditions for each dependent variable (Cohen, 1988). Statistical analyses were performed using the IBM SPSS Statistics 22 software (IBM Corporation, Armonk, NY, USA).

Results

The trial-to-trial ICC values (standard errors of measurements) for the peak pushing force for the non-injured side were: 0.96 (0.03 BW); 0.98 (0.02 BW); and 0.96 (0.03 BW) at baseline, 3-months post-surgery, and 4-month post-surgery, respectively. The trial-to-trial ICC values (standard errors of measurements) for the peak pushing force for the injured side were: 0.98 (0.02 BW); 0.98 (0.02 BW); and 0.97 (0.02 BW) at baseline, 3-months post-surgery, and 4-month post-surgery, respectively.

Non-significant differences were observed on the non-injured side for peak forces and reaching distances and on the injured side for reaching distances, as shown by non-significant ANOVA ($p \geq 0.27$). Consistently, ANOVA showed non-significant differences for reaching distance asymmetries ($p = .11$). However, ANOVA showed significant effects for peak forces for the injured side and peak force asymmetries ($p < .001$). The injured side's peak forces significantly decreased from the baseline to the 3-month post-surgery and then significantly increased between the 3-month and 4-month post-surgery assessments (Table 3). The peak forces at the 4-month post-surgery remained significantly less compared to the baseline. Effect sizes were large between the baseline and both the post-surgery assessments but were medium between the two post-surgery assessments. The magnitudes of changes in the injured side's peak force were well above the trial-to-trial standard errors of measurements among the three assessments. Consequently, peak force asymmetries were greater at the 3-month post-surgery than both the baseline and the 4-month post-surgery assessments with large effect sizes. Compared to the baseline, the force asymmetries at the 4-month post-surgery tended to be greater with a medium effect size.

Discussion

The purpose of this study was to compare the upper extremity strength and balance performance and bilateral asymmetries among pre-injury baseline and approximately 3 and 4 months after labrum surgeries in NCAA collegiate athletes. The findings supported the hypothesis that the maximal strength of the injured side would be the greatest at baseline, the second greatest at 4-month post-surgery, and the least at 3-month post-surgery. In addition, bilateral strength asymmetries were the least at baseline, the second least at 4-month post-surgery, and the greatest at 3-month post-surgery. On average, bilateral strength asymmetries were around 0% at baseline, suggesting the decreased strength of the injured arm and increased asymmetries occurred after the injuries instead of being present before the injuries.

The current findings of strength changes were generally consistent with previous studies. Pillai, Baynes, Gladstone, and Flatow (2011) showed that shoulder isometric external rotation strength improved from preoperative to postoperative assessments (average = 15.2 months) for the

Table 3. Means ± standard deviations (95% confidence intervals of the means) of dependent variables and Cohen's d_z and *p* values of pairwise comparisons.

Dependent Variables	Baseline (n = 14)	3-month post-surgery (n = 16)	4-month post-surgery (n = 12)	Cohen's d_z (*p* values): Baseline vs. 3-month post-surgery (n = 14)	Baseline vs. 4-month post-surgery (n = 10)	3-month post-surgery vs. 4-month post-surgery (n = 12)
Peak forces for the non-injured side (Body weight)	0.73 ± 0.15 (0.65, 0.81)	0.70 ± 0.15 (0.63, 0.77)	0.74 ± 0.13 (0.67, 0.82)	0.36	0.44	0.04
Peak forces for the injured side (Body weight)	0.73 ± 0.15 (0.65, 0.81)	0.60 ± 0.13 (0.54, 0.66)	0.68 ± 0.12 (0.62, 0.75)	1.24 (<0.001)	1.04 (0.009)	0.75 (0.024)
Peak force asymmetries (%)	0.00 ± 0.08 (−0.04, 0.04)	0.14 ± 0.11 (0.09, 0.19)	0.07 ± 0.10 (0.02, 0.13)	1.22 (<0.001)	0.61 (0.09)	1.02 (0.005)
Reaching distances for the non-injured side (Arm length)	1.04 ± 0.08 (1.00, 1.08)	1.04 ± 0.09 (1.00, 1.09)	1.04 ± 0.07 (1.00, 1.08)	0.02	0.01	0.44
Reaching distances for the injured side (Arm length)	1.01 ± 0.09 (0.97, 1.06)	1.03 ± 0.09 (0.99, 1.08)	1.05 ± 0.08 (1.01, 1.09)	0.16	0.38	0.00
Reaching distances asymmetries (%)	0.02 ± 0.03 (0.00, 0.04)	0.01 ± 0.04 (−0.01, 0.03)	−0.01 ± 0.03 (−0.02, 0.01)	0.31	0.77	0.37

p values of paired t-tests were calculated for the variables that demonstrated significant ANOVA.

injured side in patients following SLAP repairs, but the strength of the injured side was only at the 85% level compared to the non-injured side at the postoperative assessment. Friel, Karas, Slabaugh, and Cole (2010) assessed shoulder isometric forward flexion and external rotation strength in patients with an average of 3.4 years after SLAP repairs. Significantly decreased strength was observed for injured shoulder in non-overhead athletes. Ellenbecker, Sueyoshi, Winters, and Zeman (2008) evaluated shoulder isokinetic internal and external rotation strength at 12 weeks after labrum repairs. The injured side showed 7–11% of strength deficits in external rotation at three movement velocities and in internal rotation at two movement velocities. In the current study, the peak forces for the injured side and bilateral asymmetries improved from 3-month post-surgery to 4-month post-surgery, but the performance at 4-month post-surgery was still compromised compared to baseline. At 4-month post-surgery, only 50% of athletes had strength asymmetries less than 10%. The findings suggest time alone is an insufficient determinant of rehabilitation progress to inform an athlete's ability to return-to-play. Therefore, effective rehabilitation and valid assessments are essential for normalizing the abnormal strength of the injured arm. With decreased shoulder strength being a risk factor for future injuries (Byram et al., 2010), re-injury risk may be elevated by returning to play with decreased strength on the injured side and increased bilateral asymmetries.

The hypothesized decreases in dynamic balance performance and increases in bilateral asymmetries were not supported. On average, reaching distances did not significantly change between baseline and two post-surgery assessments. Wilk et al. (2013) described the rehabilitation protocol and indicated that the goal of restoring full range of motion could be achieved between 8 and 12 weeks. Paxinos et al. (2006) evaluated shoulder abduction, flexion, external rotation, and internal rotation range of motion in patients receiving SLAP repairs, finding shoulder range of motion recovered to preoperative levels by 3-month post-surgery. Ellenbecker, Sueyoshi, Winters, and Zeman (2008) quantified shoulder range of motion at 6 weeks and 12 weeks following labrum repairs. While deficits in shoulder abduction, external rotation, and internal rotation were observed at the 6-week assessment, the deficits in abduction and external rotation were normalized at the 12-week assessment. Friel, Karas, Slabaugh, and Cole (2010) found patients with concomitant injuries improved the range of motion in the forward flexion, abduction, external rotation, and internal rotation after a minimum of 2 years postoperatively compared with preoperative performance. The current dynamic balance assessment was different from the previous passive range of motion tests. The shoulder of the supporting arm was in a flexed and slightly abducted position without being close to the limit of its range of motion. Core stability and mobility, stability of the support arm, mobility of reaching, supporting arm strength at a low velocity all contributed to the reaching distance. Thus, it appeared that the reaching test's less explosive nature combined with a limited range of motion and the constraint of only using one arm might limit the test's ability to detect bilateral asymmetries. In summary, participants recovered to baseline dynamic balance performance at 3-month post-surgery.

The findings may provide valuable information for rehabilitation and return-to-play after labrum repairs. First, both strength and balance asymmetries were less than 10% at baseline, supporting the suggestion of using 10% of asymmetries as a criterion for rehabilitation and return-to-play (Dai et al., 2019; Kovacic and Bergfeld, 2005). Second, as the non-injured side did not demonstrate significant changes before and after labrum tears, its performance might be used as a reference to guide the rehabilitation when baseline data are not available. Third, the reaching distances did not significantly change between baseline and post-surgery assessments, suggesting the stability and mobility of the injured shoulder could be restored for most athletes 3-month post-surgery in this group of population. Fourth, strength deficits were still present after 4 months following surgeries, indicating labrum tears and surgeries had a greater effect on maximal strength compared to dynamic balance. Therefore, 4 months may not be sufficient for some athletes to restore their pre-injury strength. Fifth, the functional strength and balance tests are recommended as they can better simulate the nature of sports tasks to evaluate athletes' functional capacities. The maximal push-up test appears to be a sensitive and convenient test to assess strength impairments following labrum repairs. Restoring shoulder strength following labrum repairs was critical to making objective return-to-play decisions to decrease re-injury risk.

Several limitations should be recognized in the current study. First, the sample size was relatively small, and there was an uneven distribution of male and female participants due to the difficulty of a longitudinal study with a pre-injury baseline assessment. Future studies that incorporate multiple-testing centers may increase the sample size with sufficient female participants. Second, the participants were limited to Division I athletes, most of whom competed in contact sports. In addition, participants experienced different types of labrum tears. Future studies are encouraged to assess the effects of different types of labrum repairs and athletic populations on athletes' strength and balance performance before and after labrum tears. Third, post-surgery assessments were only performed at 3 and 4 months. Longer follow-up assessments would allow the evaluation of long-term changes and re-injury risk. Fourth, only two tests were included in the current study to reduce the time of the baseline assessment. Assessments of passive joint range of motion, isometric and isokinetic strength, and joint movement patterns might provide additional information on the post-injury progression of shoulder function. Fifth, a control group was not included, as most non-injured athletes did not find it appealing to repeat the assessment. Future studies should consider testing and retesting a control group without labrum injuries to help quantify the normal changes in strength and dynamic balance resulting from regular sports training.

Conclusion

In summary, collegiate athletes demonstrated decreased peak forces on the injured arm and increase force asymmetries, but similar reaching distances at 3-month and 4-month post-surgery assessments compared to baseline. Thus, labrum tears may affect maximal strength to a greater degree than dynamic balance. The bilateral maximal push-up test demonstrated a good sensitivity for detecting the strength deficits. Bilateral strength asymmetries were around 0% at baseline, supporting the use of less than 10% as guidelines for post-surgery rehabilitation. The performance of the contralateral side did not significantly change and might be utilized as a reference for training the injury side. With a relatively small sample size, the results support the use of objective functional assessments for strength and balance during rehabilitation, which may help inform safe return-to-play decisions among collegiate athletes following labrum repairs.

Declaration of Interest

The authors declare no conflict of interest.

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Appendix

Labral Repair Rehabilitation Guidelines

Rehabilitation Guidelines Labral Repair General Phase/Goal	SLAP Repair (Specific Phase/Goal)	Anterior + Bankart Repair (Specific Phase/Goal)	Posterior ± Labral Repair (Specific Phase/Goal)
Phase I (Begin PT 3–5 days after surgery) (1) Protection of the post-surgical shoulder (2) Activation of the stabilizing muscles of the Gleno-humeral and Scapulo-thoracic joints	To 4–6 weeks	(1) Full PROM/AAROM for shoulder flex/ext, abd/add, ER to neutral and IR	(1) Maintain ROM at the elbow and wrist (2) PROM: Flex to 120° and abduction to 90°
Phases II (4–12 weeks after surgery)	Begin 6 ~ 12 weeks after surgery (1) Full AROM and full external ROM in abduction no greater than 60° (2) Full rotator cuff strength in a neutral position	Begin at 6 weeks after surgery (1) Full AROM in all cardinal planes (2) Progress ER range of motion gradually to prevent overstressing the repaired anterior tissues of the shoulder	Begin 4–8 weeks after surgery (1) Full PROM and AROM in all cardinal planes, except internal rotation (2) Progress IR range of motion gradually to prevent over stressing the repaired posterior tissues of the shoulder at 6 weeks
		(1) Strengthen shoulder and scapular stabilizers in protected positions (0°-45° abduction) (2) Begin proprioceptive and dynamic neuromuscular control retraining	
Phase III (12 ~ 16 weeks after surgery) (1) Full AROM in all cardinal planes with normal scapulohumeral movement. (2) 5/5 rotator cuff strength at 90° abduction in the scapular plane (3) 5/5 peri-scapular strength	(1) Full external ROM in 90° abduction	Begin when criterion progression from phase II has been met~10-11 weeks	Begin at 8 weeks after surgery
Phase IV (begin when goals and criteria from phase III are met, ~ 16 weeks)		~ 15 weeks	~ 12 weeks
(1) Patient to demonstrate stability with higher velocity movements and change of direction movements. (2) 5/5 rotator cuff strength with multiple repetition testing at 90° abduction in the scapular plane (3) Full multi-plane AROM			
Phase V (begin when goals and criteria from phase IV are met, ~20 weeks)			~ 16 weeks
(1) Patient to demonstrate stability with higher velocity movements and change of direction movements that replicate sport specific patterns (including swimming, throwing, etc.) (2) No apprehension or instability with high velocity overhead movements (3) Improve core and hip strength and mobility to eliminate any compensatory stresses to the shoulder (4) Work capacity cardiovascular endurance for specific sport or work demands			