Distal Biceps Tendon Repair in Competitive Strength Athletes

A Retrospective Series of 183 Athletes

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Background: Elbow injuries are common among strength athletes, particularly distal biceps tendon ruptures. These injuries can significantly affect athletes' performance and require effective treatment strategies to ensure optimal recovery and return to sport.

Purpose/Hypothesis: The purpose of this retrospective cohort study was to evaluate the patient-reported outcomes, return-to-sport rate, and postoperative strength of competitive strength athletes who underwent distal biceps tendon repair. It was hypothesized that patients would show excellent patient-reported outcomes on validated questionnaires and exhibit high rates of return to sport as well as high subjective strength levels.

Study Design: Case series; Level of evidence, 4.

Methods: A retrospective chart review was performed for cases of distal biceps tendon repair in athletes competing in strength sports, such as weightlifting and powerlifting, between August 2003 and July 2020. The preoperative and postoperative sporting activity, mechanism of injury, and complications were assessed. Clinical outcomes were evaluated using the Mayo Elbow Performance Score (MEPS) and the Single Assessment Numeric Evaluation (SANE). Additionally, the athletes were asked to rate their elbow strength as a percentage compared with their uninjured side.

Results: A total of 183 patients were included (88% follow-up rate), with a mean follow-up of 69.6 ± 61.0 months. Among them, 168 underwent primary repair, while 15 underwent revision procedures, of which 7 involved allograft augmentation. All athletes were able to return to sport, and 73% of patients achieved full subjective strength of their affected arm. The median MEPS score was 100 (interquartile range, 100-100), and the median SANE score was 100 (interquartile range, 95-100). Multivariate linear regression analysis showed that an increased time between injury and surgery was associated with a decrease in the MEPS score (standard error [SE] = 0.002; $t = -2.113$; $P = .036$) and self-assessed strength (SE = 0.053; $t = -3.183$; $P = .002$). Graft usage was associated with a nonsignificant decrease in the SANE score (SE = 1.538; $t = -1.791$; $P = .075$). There were 28 complications (15%) that occurred, including 5 tendon retears (3%) and 1 intraoperative brachial artery injury (1%).

Conclusion: Distal biceps tendon repair in competitive strength athletes resulted in a high return-to-sport rate and excellent recovery. However, delayed surgery negatively affected outcomes, and 27% of patients experienced persistent subjective strength deficits. Future research is needed to further optimize treatment strategies for athletes.

Keywords: biceps tendon rupture; tendon repair; athletes; weight training; strength training; postoperative outcome

The elbow is affected in 7% to 35% of all injuries in strength sports such as weightlifting, powerlifting, bodybuilding, strongman competitions, Highland games, and CrossFit.[3,4,6,7,9,25] Athletes involved in strength sports are especially at risk for elbow injuries because of the heavy loads and repetitive movements inherent in these activities.[10] The high-intensity training and competitions associated with these sports can lead to acute injuries such as dislocations, fractures, and tendon ruptures as well as chronic overuse injuries.[23] These athletes typically have high functional demands and require treatment that allows for a quick return to sport and the restoration of elbow function to avoid jeopardizing their athletic careers.[22] Therefore, specific data on outcomes for athletes engaging in these high-demand sports are essential to provide the most effective treatment plans.

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Distal biceps tendon ruptures are among the most common elbow injuries in strength athletes,[12] who are up to 3 times more likely to suffer from distal biceps tendon ruptures than the general population.[22] Surgical treatment is often recommended for distal biceps tendon ruptures because of the potential loss of 36% in flexion strength and 55% in supination strength.[15] Various repair techniques exist, each with its own merits. Double- or single-incision approaches can be used, and fixation methods include inlay and onlay techniques in which the tendon is either embedded within the bone or placed on top of it. Additionally, for chronic or severe cases in which direct repair is not feasible, reconstruction using allografts can be employed. Furthermore, various anchor systems, such as interference screws, suture buttons, and suture anchors, are available for distal biceps tendon repair.[1,13,24] However, data on outcomes after distal biceps tendon repair in athletes are sparse. A recently published systematic review by Pitsilos et al[20] found only 157 cases in the current scientific literature.

The aim of this retrospective cohort study was to evaluate the patient-reported outcomes, return-to-sport rate, and postoperative subjective strength of competitive strength athletes who underwent distal biceps tendon repair. It was hypothesized that patients would show excellent patient-reported outcomes on validated questionnaires and exhibit high rates of return to sport as well as high subjective strength levels. By incorporating both validated outcome instruments and subjective measures, the study aimed to provide a comprehensive analysis of functional recovery and athletic performance after repair.

METHODS

Patient Population

Institutional review board approval was obtained before the initiation of this study (2023-278-S-KH). A retrospective chart review was conducted for all cases of distal biceps tendon repair performed in competitive strength athletes between August 2003 and July 2020 at the senior author's (M.R.) institution, which specializes in treating injuries specific to strength athletes. Strength athletes were defined as those who engaged in high-intensity strength training aimed at building muscle strength and hypertrophy through resistance exercises prioritizing the development of maximal strength, anaerobic capacity, power, and muscular endurance.[16,26] This includes sports such as weightlifting, powerlifting, bodybuilding, strongman competitions, Highland games, and CrossFit. Athletes were considered competitive if they participated in competitions during the year of their injury. All tendon ruptures, including partial tears, were diagnosed preoperatively using magnetic resonance imaging. Athletes who were aged $\geq$18 years with a minimum follow-up of 12 months were included in the study. Exclusion criteria were relevant concomitant injuries of the affected arm, such as fractures, as well as relevant comorbidities, such as rheumatic diseases and cervical or peripheral neuropathies.

Data Collection

Patients who met the inclusion criteria were contacted for follow-up data collection, which included the preoperative and postoperative sporting activity, mechanism of injury, and self-reported elbow strength. To assess elbow strength, participants were asked to express their strength as a percentage of their uninjured side during one repetition of a weightlifting exercise such as biceps curls. The patients' medical records were reviewed retrospectively for age at the time of surgery, sex, body mass index (BMI), surgical approach, fixation method, and complications. Patient-reported outcomes were assessed using the Mayo Elbow Performance Score (MEPS) and the Single Assessment Numeric Evaluation (SANE).

Surgical Technique

All surgical procedures were performed by a single elbow surgeon (M.R.) using an onlay technique, as previously described by Ritsch.[22] Patients were positioned supine, and an incision was made on the volar side of the elbow at the joint level, which extended distally. The fascia was opened, and the lateral antebrachial cutaneous nerve was identified and dissected. The radial tuberosity was then visualized, and 2 titanium or all-suture anchors (or in cases of a partial rupture, 1 anchor) were inserted for tendon fixation. If the biceps tendon could not be grasped via the primary incision, an additional horizontal incision was made proximally to mobilize the tendon. Sutures originating from the anchors were passed through the tendon in a Krackow fashion. The tendon was then fixed to the tuberosity at 90° of elbow flexion.

Tendon repair with an allograft was performed on patients with chronic tears, extensive tendon retraction, or insufficient tendon quality, making anatomic repair unfeasible. In these cases, allografts from the tensor

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Ethical approval for this study was obtained from Klinikum Rechts der Isar, Technische Universität München (2023-278-S-KH).

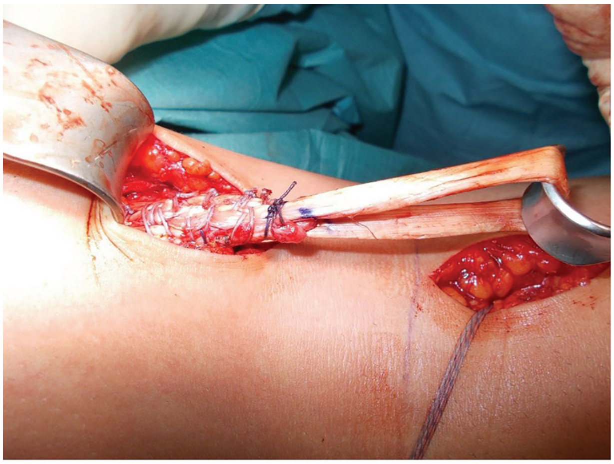

Figure 1. For tendon repair, an incision was made at the joint level, extending distally. The radial tuberosity was then visualized, and anchors were inserted for tendon fixation. If the biceps tendon could not be grasped via the primary incision, an additional horizontal incision was made proximally to mobilize the tendon. Tendon repair with an allograft was performed on patients in whom anatomic repair was unfeasible. The allograft was doubled, and the free ends were sutured to the tendon stump. The distal end of the allograft was then used for tendon fixation.

fasciae latae, semitendinosus, or gracilis tendons were used. Mobilization of the tendon stump in these cases was always carried out through a second cranial skin incision. After measuring the required length, the allograft was doubled and, after preparing the tendon stump, was initially sutured externally to it with interrupted sutures and additionally secured with Orthocord (DePuy Synthes) (Figure 1).

For tendon stump lengths <3 cm, the graft was also sutured to the biceps muscle. The graft was then fixed to the radial tuberosity with suture anchors, as described for primary refixation. At 70° of elbow flexion, the distal biceps tendon extended with the allograft showed firm tension.

Postoperative Rehabilitation

Postoperatively, the patient was given instructions to rest and protect the arm. Physical therapy was usually initiated after a certain healing period to restore the arm's mobility and strength. The affected arm was immobilized in a brace at 70° of flexion for 6 weeks. For the following 4 weeks, load-free mobilization with free passive and active range of motion was performed. Regular follow-up appointments were scheduled to monitor the progress of healing. Physical therapy was conducted at least twice a week, with some patients receiving more intensive care through their athletic team. From the 13th postoperative week onward, increased loading of the affected arm was permitted. Weightlifting without restrictions was allowed at 6 months postoperatively.

Statistical Analysis

All statistical analyses were performed using SPSS Statistics (Version 25; IBM). Categorical variables were reported as counts and percentages. Continuous variables were reported as the mean ± standard deviation when normally distributed or as the median and interquartile range (IQR) when not normally distributed. Pearson correlation analysis was used for normally distributed continuous variables, while Spearman correlation analysis was used for ordinal and nonnormally distributed variables to assess relationships between variables. Multicollinearity diagnostics, including the variance inflation factor, were performed to ensure no significant multicollinearity issues among predictors. Potential predictors included age, graft usage, BMI, years of athletic participation, training frequency, and days between injury and surgery, which were chosen based on their clinical relevance and potential effect on outcomes. Multivariate linear regression analysis was employed to determine the independent predictors of postoperative strength, MEPS score, and SANE score. Additionally, logistic regression analysis was conducted to assess the effect of the same predictors on the occurrence of complications. Statistical significance was set at $P < .05$.

RESULTS

A total of 208 athletes met the inclusion criteria, of whom 183 were available for follow-up (88%). Follow-up was conducted at a mean of 69.6 ± 61.0 months postoperatively.

Mechanism of Injury

In 98 cases (54%), the rupture occurred during sporting activities (Figure 2). The most common strength sport activities leading to a distal biceps tendon rupture were deadlifting (20%) and biceps curls (13%), while boxing (18%) was the most common non–strength sport activity. Outside of sporting activities, the most common mechanisms of injury were lifting (34%) or carrying (11%) a heavy object and falling onto the outstretched arm (13%).

Patient Characteristics

The median frequency of training sessions was 4 sessions per week (IQR, 3-5). The included athletes had been participating in strength sports for a median of 15 years (IQR, 8-20 years) at the time of injury. All but 3 of the included patients were male. The mean age at the time of surgery was 39.7 ± 7.8 years. Additionally, 57% of the ruptures were acute, and 15 revision cases (8%) were included. Allograft augmentation was performed in 7 cases (4%). Table 1 provides an overview of patient characteristics.

Distal biceps tendon repair was performed using 2 anchors in 74% of cases. The most commonly used anchors were all-suture anchors (1.5-, 1.7-, or 2.9-mm JuggerKnot; Zimmer Biomet) in 138 cases. These were followed by

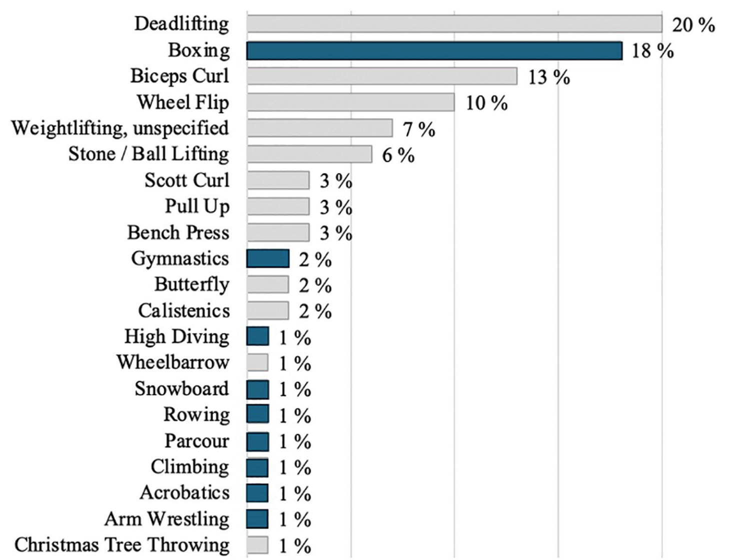

Figure 2. Distribution of sporting activities (n = 98) leading to a distal biceps tendon rupture. Although all injuries occurred in strength athletes, activities marked in gray represent those that happened during strength sport training or competitions, while activities marked in blue indicate injuries sustained during other types of sporting activities outside of strength sports.

TABLE 1
Patient and Injury Characteristics (n = 183)[a]

	Value
Age, y	39 (34-46)
Male sex	180 (98)
BMI, kg/m^2	31 (28-34)
Follow-up, mo	69.6 ± 61.0
Time to surgery, d	12 (6-39)
Acute rupture (<30 d)	104 (57)
Revision repair	15 (8)
Partial tendon rupture	47 (26)
Allograft augmentation	7 (4)
Semitendinosus tendon	4 (2)
Gracilis tendon	2 (1)
Tensor fasciae latae tendon	1 (1)

[a]Data are shown as mean ± SD, median (interquartile range), or n (%). BMI, body mass index.

titanium anchors (G4 or G2; DePuy Synthes) in 35 cases and polymer anchors (Panalok RC; DePuy Synthes) in 4 cases.

Functional Outcomes

All athletes were able to return to sport. There were 50 athletes (27%) who reported not having fully regained strength in their arm after surgery. However, the median self-assessed postoperative strength was 100% (IQR, 95%-100%). The median MEPS score was 100 (IQR, 100-100), and the median SANE score was 100 (IQR, 95-100).

Spearman correlation analysis revealed a weak but statistically significant correlation between years of athletic participation and the MEPS score (rho = 0.168; P = .024). Additionally, self-assessed strength was moderately strongly correlated with both the SANE (rho = 0.561; P < .001) and MEPS (rho = 0.404; P < .001) scores.

Multicollinearity diagnostics showed no significant multicollinearity issues among the predictors. All variance inflation factor values were <2, indicating that multicollinearity did not substantially affect the stability and interpretation of the regression coefficients. Multivariate linear regression analysis revealed that each additional day between injury and surgery was significantly associated with a 0.005-point decrease in the MEPS score (standard error [SE] = 0.002; t = −2.113; P = .036) and a 0.169% decrease in self-assessed strength (SE = 0.053; t = −3.183; P = .002). Also, each added year of athletic participation was significantly associated with a 0.129-point increase in the MEPS score (SE = 0.055; t = 2.354; P = .020), while each additional training session per week was significantly associated with a 0.806-point decrease in the MEPS score (SE = 0.347; t = −2.326; P = .021). Furthermore, graft usage was marginally associated with a 2.754-point decrease in the SANE score, although this association was not statistically significant (SE = 1.538; t = −1.791; P = .075).

Complications

Overall, 28 complications (15%) occurred (Table 2). The most common complication was temporary lateral antebrachial cutaneous nerve dysesthesia. Additionally, there was 1 intraoperative brachial artery injury (1%).

There were 5 tendon retears (3%) that were observed at 4 to 8 weeks after surgery, 4 of which occurred in chronic ruptures (Table 3). Logistic regression analysis revealed

TABLE 2
Complications (n = 28)

	n (%)
Temporary lateral antebrachial cutaneous nerve dysesthesia	15 (8)
Retear	5 (3)
Ossification	3 (2)
Hematoma requiring surgery	1 (1)
Tendinopathy	1 (1)
Joint stiffness	1 (1)
Brachial artery injury	1 (1)
Jumping sensation in tendon	1 (1)

TABLE 3
Characteristics of Patients With Retears (n = 5)[a]

Sex	Age, y	Chronicity of Injury	Time to Retear, wk	Strength, %	MEPS	SANE
Female	44	Chronic	4	90	90	85
Male	35	Acute	6	90	90	85
Male	41	Chronic	7	90	90	85
Male	40	Chronic	8	90	90	85
Male	35	Chronic	7	90	90	85

[a]MEPS, Mayo Elbow Performance Score; SANE, Single Assessment Numeric Evaluation.

that none of the variables examined showed significant associations with complications (all $P > .05$).

DISCUSSION

The main findings of this study were that distal biceps tendon repair in competitive strength athletes resulted in excellent patient-reported outcomes, a high return-to-sport rate, and excellent recovery of subjective strength of the affected arm. To the best of our knowledge, this is the largest series of distal biceps tendon repair procedures performed in this athlete population to date.

Returning to the preinjury level of sporting activity as quickly as possible while regaining full joint functionality is crucial for injured athletes.[20] While successful nonoperative treatment for distal biceps tendon ruptures has been reported,[2] surgical repair is generally recommended for strength athletes because of their high functional demands. A recently published systematic review reported 157 cases of distal biceps tendon repair in athletes[20]; thus, the 183 cases in the current study significantly contribute to the limited existing data.

All athletes in the present study were able to return to sport, consistent with a 97.5% return rate reported in the literature.[12] Excellent MEPS and SANE scores were achieved, and all but 27% of athletes regained full subjective elbow strength. It should be noted, however, that only self-assessed strength was evaluated, and no objective strength measurements were obtained. Yet, Strøyer et al[27] demonstrated that self-assessed muscle strength has moderate construct validity and moderate to good reliability. Similarly, Rincon et al[21] showed that patients reporting higher self-perceived strength also performed better on objective field tests. When assessing subjective elbow strength, activities such as biceps curls were evaluated in the present study. While supination strength is more likely affected than flexion strength in cases of distal biceps tendon ruptures, evaluating supination strength seemed hard to grasp for athletes. Therefore, a more practical example, such as biceps curls, was chosen.

Gowd et al[5] reported that a majority of patients regained good elbow strength after distal biceps tendon repair but that only 65.6% returned to their preoperative performance level. However, that study included both athletes and nonathletes. In contrast, a study on National Football League athletes found that 16% were unable to return to play.[18] Despite overall promising results, athletes should be informed that while returning to preinjury performance is common, it is not guaranteed.

The present study exclusively consisted of competitive strength athletes and demonstrated that distal biceps tendon repair yielded good results in this demanding cohort. However, the use of performance-enhancing drugs, such as anabolic-androgenic steroids and human growth hormone derivatives, is common among strength athletes.[14] While these substances can enhance performance, they may also increase the risk of tendon retears.[8] Conversely, Pagonis et al[19] suggested that users of anabolic-androgenic steroids may experience quicker and better outcomes after distal biceps tendon repair. However, these findings should be interpreted with caution; as the use of performance-enhancing drugs was not queried in the present study, no definitive conclusions can be made regarding their effect.

Gowd et al[5] reported associations of injury chronicity and BMI with a return to previous performance levels after distal biceps tendon repair. Similarly, in the present study, the time between injury and surgery was significantly associated with postoperative outcomes, and graft usage had a negative effect on the SANE score. Additionally, each year of athletic participation was linked to an increase in the MEPS score, whereas more training sessions per week was associated with a decrease in the MEPS score. Possibly, a higher frequency of training sessions per week could lead to cumulative fatigue, overuse injuries, or inadequate recovery time, negatively impacting postoperative recovery. Unlike Gowd et al's[5] findings, BMI was not a significant factor in our study possibly because only athletes were included, whereas Gowd et al[5] included both athletes and nonathletes.

The majority of the repair procedures were performed using all-suture anchors. Previous studies have reported that all-suture anchors have equivalent biomechanical properties to other types of anchors for distal biceps tendon repair.[17] Additionally, a recent study showed promising early outcomes using all-suture anchors.[11] However, available data remain limited. To our knowledge, this study is the first to report that all-suture anchors were suitable for distal biceps tendon repair in strength athletes. Yet, subgroup analysis between different anchors was not feasible because of the small sample size and varying follow-up times.

In the present study, a notably high rate of chronic cases in distal biceps tendon repair was observed. This finding may be attributed to the prevalence of partial tears, which athletes may have underestimated, leading to delays in seeking an appropriate medical intervention. Additionally, the significance of competitive events likely exacerbated this issue, as athletes may prioritize continued participation over immediate treatment, thereby risking further injuries and the progression to a chronic state.

Limitations

Several limitations of this study must be acknowledged. First, the retrospective study design may have led to recall bias regarding patients' preoperative sport activity levels and strength. Additionally, there was a heterogeneity of surgical techniques. Although regression analysis was performed, the dataset was not balanced to adequately account for every variable. Furthermore, no objective strength measurements or assessments of athletic performance were included; instead, patients were asked to subjectively self-assess their strength compared with their uninjured side at follow-up.

CONCLUSION

Distal biceps tendon repair in competitive strength athletes resulted in a high return-to-sport rate and excellent recovery. However, delayed surgery negatively affected outcomes, and 27% of patients experienced persistent subjective strength deficits. Future research is needed to further optimize treatment strategies for athletes.

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