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Lower trapezius tendon transfer for massive irreparable rotator cuff tears improves outcomes in patients with high grade fatty infiltration of teres minor

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Background: This study compares postoperative outcomes of lower trapezius tendon transfers (LTTTs) in massive irreparable rotator cuff (RC) tears based on the degree of teres minor (TM) fatty infiltration.
Methods: In this prospective longitudinal observational study, patients with massive RC tears undergoing arthroscopic-assisted LTTT by two surgeons were screened. TM fatty infiltration on preoperative magnetic resonance imaging was graded using the Goutallier classification. Two groups were created as follows: group A included grades 0 and 1 (no or little fatty infiltration), and group B included grades 2 to 4 (moderate-to-severe fatty infiltration). Participants completed the Single Assessment Numeric Evaluation (SANE) score preoperatively, and 12- and/or 24 months postoperatively along with a clinical assessment. Independent t-tests compared groups, and paired t-tests compared pre-vs. postoperative results. Significance was defined as $P < .05$.
Results: There were 47 patients in group A and 19 in group B. No group differences were found in preoperative SANE score, forward elevation or active external rotation (ER). Both groups showed significant postoperative improvements in SANE score with no differences between the groups. An ER lag sign was observed in 18/47 patients (38.3%) in group A and 11/19 patients (57.9%) in group B ($P = .177$). Preoperative ER strength was significantly different in group A (2.9 kg) vs. group B (0.7 kg; $P = .001$), but postoperative ER strength was similar ($P = .931$).
Conclusion: LTTT is a suitable salvage procedure regardless of the degree of TM fatty infiltration and should be considered an alterative procedure to latissimus dorsi tendon transfer in patients with high-grade TM fatty infiltration.

Rotator cuff (RC) tears are one of the most common pathologies affecting the shoulder.[11] Massive RC tears extend beyond 5 cm in the anterior to posterior direction, involve 2 or more of the RC tendons, or uncover >67% of the greater tuberosity footprint.[17] Many patients with massive RC tears experience high pain levels and/or poor range of motion. Patients with massive postero-superior tears may lack active external rotation (ER) or experience a functional deficit of ER.

Although direct repair of acute massive RC tears can be successful, chronic tears with poor tendon quality necessitates the use of alternative procedures to restore function and provide pain relief. While reverse shoulder arthroplasty is a reasonable surgical option for patients with RC arthropathy and/or advanced age, its use in the younger patient population with massive irreparable cuff tears is suboptimal with complication rates reported at 22.4%.[8,15] The optimal treatment for massive irreparable posterosuperior cuff tears in young patients therefore presents a significant therapeutic challenge. Younger patients with massive irreparable cuff tears are often provided with alternative salvage options, such as superior capsular reconstruction (SCR) or tendon transfers, to restore range of motion, improve function, and provide pain relief.[1]

University of Manitoba Biomedical Research Ethics Board B2018:135 and the Emory University Institutional Review Board 00105874 approved this study.

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Tendon transfers have gained popularity in young patients with massive irreparable RC tears. The two most common tendon transfers in patients with massive irreparable RC tears are the latissimus dorsi tendon transfer (LDTT) and lower trapezius tendon transfer (LTTT). Both types of tendon transfer provide improvement in objectively measured and patient-reported outcomes.[5,22] However, patients with high-grade fatty infiltration of the teres minor (TM) muscle demonstrated poor outcomes compared to patients with minimal or no TM fatty infiltration following LDTT.[3] This led to the conclusion that high-grade fatty infiltration of the TM should be considered a relative contraindication to performing a LDTT. The influence of TM fatty infiltration on outcomes following LTTT has not been evaluated. Biomechanical studies suggest that compared to the LDTT, the LTTT provides a line of pull, which more closely replicates the native direction of activity of the infraspinatus and TM tendons, and therefore may not be similarly influenced by TM fatty infiltration.[14]

The purpose of this study was to evaluate patients who underwent LTTT for the treatment of massive irreparable RC tears to determine if the degree of fatty infiltration of TM influences patient-reported outcome measures, shoulder range of motion, and ER strength. We hypothesize that LTTT will provide improved patient-reported and objective range of motion and strength-based outcomes independent of the degree of fatty infiltration to the TM.

Materials and methods

This was a prospective longitudinal observational study conducted by two upper extremity fellowship-trained orthopedic surgeons at two university-affiliated teaching centers.

Participants

Consecutive patients presenting to one of the two participating surgeons in their orthopedic outpatient clinics with a massive RC tear confirmed on magnetic resonance imaging (MRI) that had failed with more than three months of nonoperative management were screened for study eligibility. Inclusion criteria were: 1) a massive irreparable RC tear on preoperative MRI, 2) arthritic Hamada grade of <3 on standardized anteroposterior preoperative X-rays, 3) a minimum of 12 months of follow-up, and 4) a minimum 18 years of age.

Massive RC tear size was defined on MRI as two or more RC tendons or uncovering of the greater tuberosity of >67%.[17] Irreparability was defined as two or more of the following: 1) infraspinatus fatty infiltration at Goutallier grade II or greater; 2) supraspinatus tendon length <15 mm; 3) Patte grade 3; and 4) previously failed RC repairs. If the patient was deemed eligible and agreed to discuss participation in the study, the informed consent process was undertaken by a research coordinator. Final eligibility was confirmed during the index operation. Intraoperative exclusion criteria were as follows: 1) the presence of an irreparable subscapularis tear and 2) grade 4 chondromalacia of the humeral head or glenoid.

Outcome measures

The primary outcome measure of this study was patient-reported outcome measures, while secondary outcomes included shoulder range of motion and ER strength. Functional measurements for ER strength were measured using a hand-held dynamometer (Mark-10 Series 3; Mark-10 Corporation, Copiague, New York). At each follow-up visit, eligible participants completed the Single Assessment Numeric Evaluation (SANE) score. The SANE score is a self-reported assessment, which provides a single numeric value reflecting overall function and satisfaction.[20] Range of motion measurements, including forward elevation (FE) and ER, were measured directly in degrees. The number of surgical failures was also determined, defined as a SANE score of $\leq$50%, FE <90 degrees, or second surgery performed or offered within the study period. TM fatty infiltration was graded on preoperative MRI using the Goutallier classification by two fellowship-trained orthopedic surgeons not involved in performing the surgeries.[6] Participants were categorized into two groups as follows: group A included patients with little or no fatty infiltration of the TM (grades 0 and 1) and group B included patients with moderate or severe fatty infiltration of the TM (grades 2, 3, or 4).

Study protocol

Upon consent, participants completed a preoperative baseline visit, and postoperative study visits were conducted at 6, 12, and 24 months. Patient-reported outcomes were completed, and a clinical assessment was performed by a trained research coordinator (physical or athletic therapist). Approval for this study was obtained from the University of Manitoba Bannatyne Campus Research Ethics Board and the Emory University Research Ethics Board before the commencement of study activities. The authors have no conflicts of interest relevant to this study to disclose

Surgery

An arthroscopic-assisted LTTT was performed using Achilles tendon allograft in a standardized manner, as previously described.[4] The lower trapezius tendon was isolated with a mini-open procedure along the posterior acromial spine. The Achilles allograft was prepared on the back table and inserted into the shoulder through the posterior incision in a subdeltoid position after all required concomitant procedures were completed (eg, biceps tenotomy or tenodesis, subscapularis repair, acromioplasty, partial RC repair) and secured to the greater tuberosity with two commercially available anchors. With the arm in 60 degrees of abduction and ER, the Achilles allograft was then secured to the isolated lower trapezius tendon in a transtendinous pulvertaft fashion. Patients were placed into an ER or abduction sling postoperatively for 6 weeks and followed a standardized physiotherapy protocol.

Statistics

Between group comparisons were performed using independent student t-tests assuming equal variance. Pre-vs. postoperative comparisons were performed for each group using paired t-tests. The rate of ER lag sign was compared between groups using a chi-square test. Failure within the postoperative study period was defined as either a SANE score $\leq$50, FE $\leq$60 degrees, or having completed or consented to revision surgery. Significance was defined as $P < .05$. Tukey's least significant difference was used for adjusting for multiple comparisons.

Results

A total of 66 patients screened from a massive irreparable RC tear prospective database undergoing arthroscopic-assisted LTTT met full criteria for inclusion in the study. Preoperative MRI analysis of the ipsilateral shoulder stratified 47 patients into group A (Goutallier grade 0 and 1) and 19 patients into group B (Goutallier

Table I
Patient demographics for group A (Goutallier grades 0 and 1 (G0-1)) and group B (Goutallier grades 2, 3, and 4 (G2-4)).

	Group A	Group B
Number	47	19
Age (mean[range])	59.0 y [39-73]	56.7 y [43-74]
Sex (F:M)	9:36	4:15
Revision surgery	10	7
WCB	6	3

WCB, Worker's Compensation Board; *F*, female; *M*, male.

Table II
Pre-vs. postoperative Single Assessment Numeric Evaluation (SANE) scores for group A (Goutallier grades 0 and 1 (G0-1)) and group B (Goutallier grades 2, 3, and 4 (G2-4)).

	Group A	Group B	*P* value
SANE preop (mean[SD])	35.4 [18.5]	28.1 [14.4]	.119
SANE >12 mo (mean[SD])	79.6 [17.1]	76.9 [18.6]	.604
P value (pre- vs. postoperative)	**.000***	**.000***	

SD, standard deviation.
*Significant difference between groups ($P < .05$).

grades 2, 3, and 4). Patient demographics for groups A and B are shown in Table I.

Preoperative values for SANE score are shown in Table II. Pre-vs. postoperative comparison of each group demonstrated statistically significant improvement in SANE scores (group A, $P = .000$; group B, $P = .000$; Table II and Fig. 1). No significant difference was found between groups either preoperatively ($P = .119$) or postoperatively ($P = .604$).

Range of motion measurements for pre and postoperative assessments for degrees of active FE and ER are shown in Table III and Figs. 2 and 3. Comparison between the two groups demonstrated no statistically significant difference in preoperative range of motion measurements (FE, $P = .437$; ER, $P = .120$), or postoperative range of motion measurements (FE, $P = .252$; ER, $P = .146$). Both groups experienced a statistically significant increase in pre-vs. postoperative FE and ER ($P < .002$ in all comparisons).

An ER lag sign was noted in 18/46 (39.1%) patients in group A, compared to 11/19 (57.9%) patients in group B preoperatively, though this difference was not found to be statistically significant ($P = .177$, Table IV). ER strength was significantly different in group A (2.9 kg) vs. group B (0.7 kg) in baseline preoperative measurements ($P = .001$, Table IV and Fig. 4). This difference was no longer noted in postoperative measurements ($P = .931$).

Failure within the postoperative study period was defined as either SANE score ≤50, FE ≤60 degrees, or having completed or consented to revision surgery. One of the 46 (6.5%) patients in group A had a SANE score ≤50, while 4/46 (8.7%) had revision surgery. Two of the 46 patients had both a SANE score ≤50 and revision surgery. One of the revision surgeries required conversion to reverse shoulder arthroplasty; one involved latissimus transfer to subscapularis and other intra-articular arthroscopic procedures; and 4 involved minor procedures for wound infection, bicipital groove débridement, or other arthroscopic débridement procedure(s). One of 19 (5.3%) of patients in group B had a SANE score < 50, while 4/19 (21.0%) had revision surgery, with two revisions to reverse shoulder arthroplasty, one revision to LDTT with other intra-articular arthroscopic procedures, and one minor procedure for biceps tenotomy and groove débridement. No patients in either group met criteria for failure based on FE ≤60 degrees.

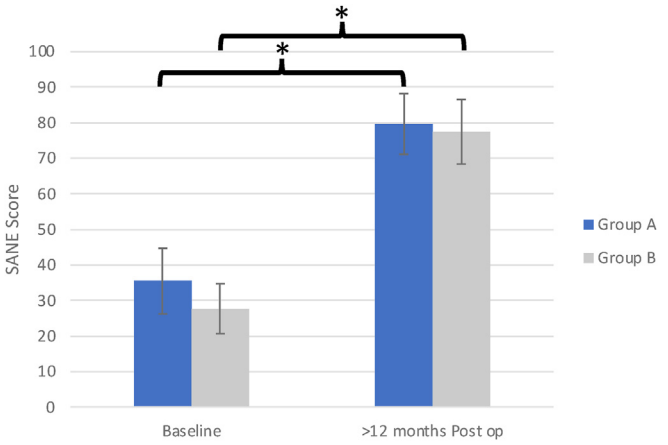

Figure 1 Pre-vs. postoperative Single Assessment Numeric Evaluation (SANE) scores for group A (Goutallier grades 0 and 1 (G0-1)) and group B (Goutallier grades 2, 3, and 4 (G2-4)). (*) represents significance at $P < .05$.

Table III
Pre-vs. postoperative range of motion for group A (Goutallier grades 0 and 1 (G0-1)) and group B (Goutallier grades 2, 3, and 4 (G2-4)).

	Group A	Group B	*P* value
FE preop (mean[SD])	118.3 [35.9]	110.5 [36.1]	.437
FE > 12 mo (mean[SD])	161.4 [16.8]	152.2 [29.5]	.252
P value (pre vs. postoperative)	**.000***	**.002***	
ER preop (mean[SD])	23.8 [25.7]	10.8 [30.3]	.120
ER > 12 mo (mean[SD])	53.4 [21.7]	42.3 [26.8]	.146
P-value (pre vs. postoperative)	**.000***	**.002***	

FE, forward elevation; *ER*, external rotation; *SD*, standard deviation.
*Significant difference between groups ($P < .05$).

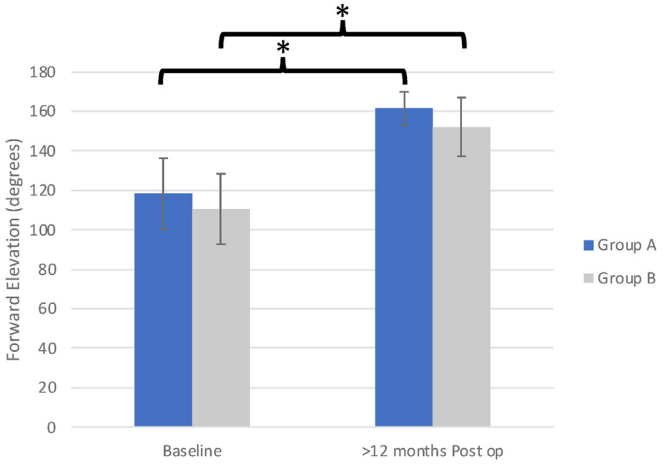

Figure 2 Pre-vs. postoperative FE for group A (Goutallier grades 0 and 1 (G0-1)) and group B (Goutallier grades 2, 3, and 4 (G2-4)). (*) represents significance at $P < .05$.

Discussion

In patients with massive irreparable RC tears, LTTT significantly improves patient-reported outcome measures, regardless of the degree of fatty infiltration to the TM. Postoperative ER strength was restored to similar levels despite patients with high fatty infiltration of TM having significantly lower ER strength at baseline. This study demonstrates that LTTT is a suitable salvage procedure for any degree of TM fatty infiltration and should be strongly considered over LDTT in patients with high-grade TM fatty infiltration.

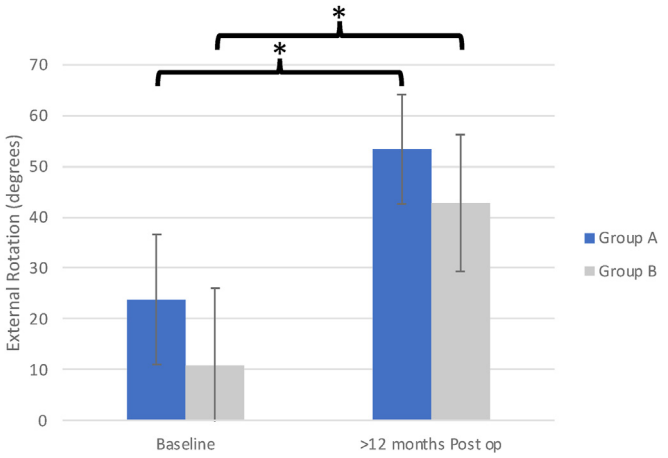

Figure 3 Pre-vs. postoperative external rotation for group A (Goutallier grades 0 and 1 (G0-1)) and group B (Goutallier grades 2, 3, and 4 (G2-4)). (*) represents significance at $P < .05$.

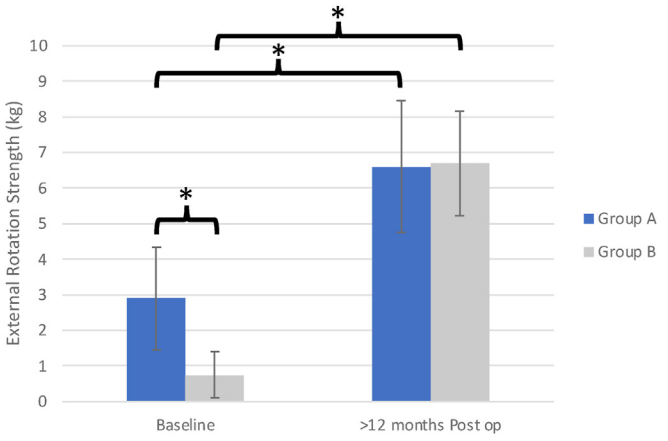

Figure 4 Pre-vs. postoperative isokinetic external rotation strength (in kilograms) for group A (Goutallier grades 0 and 1 (G0-1)) and group B (Goutallier grades 2, 3, and 4 (G2-4)). (*) represents significance at $P < .05$. (kg: kilograms).

Table IV
Pre-vs. postoperative external rotation lag sign (present vs. absent) and isokinetic external rotation strength (kilograms) for group A (Goutallier grades 0 and 1 (G0-1)) and group B (Goutallier grades 2, 3, and 4 (G2-4)).

Outcome	Group A	Group B	*P* value
ER lag sign preoperative	18/46	11/19	.177
ER lag sign at >12 mo	1/46	0/19	1
ER strength (mean[SD])	2.9 [2.9]	0.7 [1.3]	**.001***
ER strength >12 mo (mean[SD])	6.6 [3.7]	6.7 [2.9]	.931
P value (pre- vs. postoperative)	**.000***	**.000***	

ER, external rotation; *SD*, standard deviation.
*Significant difference between groups ($P < .05$).

Massive irreparable RC tears in young patients, though not a common pathology, present considerable challenges in treatment as there is currently no ideal operative intervention to restore optimal mechanics in this otherwise high-functioning patient group. Salvage options have focused on SCR and tendon transfers in the recent literature. While SCR is a reasonable intervention to provide static depression of the humeral head and centralization on the glenoid, its utility in patients with severe ER weakness or an ER lag and an irreparable infraspinatus or TM complex is limited.[23] In fact, failure rates exceeding 50% have been observed in the setting of high-grade fatty infiltration of the external rotators. Tendon transfers offer the theoretical advantage of restoring both static depression of the humeral head and dynamic function of the posterior force couple. However, when LDTTs were performed on patients with advanced TM fatty infiltration, poor outcomes were observed, rendering this pathology a relative contraindication for LDTT.[3] The results of the current study contradict the previous literature, demonstrating significantly improved SANE scores when LTTT is performed in the setting of moderate-to-high-grade fatty infiltration of TM.

LTTT has gained considerable popularity in recent years due to its biomechanical and kinematic advantages when compared to the LDTT.[14,18,21] TM has become increasingly recognized for its role in maintaining ER and function in patients with massive RC tears.[2] The muscle fibers of the lower trapezius pull in line and in phase with the infraspinatus and TM muscle fibers. The more anterior and inferior origin of the latissimus dorsi muscle on the posterior thorax results in a pull vector that is out of line and out of phase following tendon transfer. Furthermore, electromyographic studies corroborate that the lower trapezius electrical activity mimics the timing and position of activity compared to infraspinatus activity.[18,21] Although prior retrospective studies have demonstrated similar clinical and patient-reported outcomes in patients with arthroscopic-assisted LTTT compared to arthroscopic-assisted LDTT,[24] this study suggests that the improved biomechanics of the LTTT may provide advantages in the restoration of ER.

Functional ER of the shoulder refers to the ability to perform active ER with sufficient range to perform activities of daily living as well as to perform these motions with sufficient strength to have meaningful function. In this study, a large proportion of the participants presented with ER lag signs with a mean ER of 10.8 to 23.8 degrees (Table III). The minimum ER of the shoulder necessary for daily tasks has been measured between 35 and 59 degrees.[7,12] Similarly, a biomechanics study performed in 2012 quantified how restriction of ER of the shoulder with an orthosis affected the perceived ability to perform various activities of daily living.[10] We found that LTTT provided significant improvements in ER to 53.4 and 42.3 in groups A and B, respectively, allowing for the restoration of ER to a degree that accommodates activities of daily living. In a series of normal volunteers with minimal shoulder dysfunction, isometric ER strength at 45 degrees of abduction was measured at an average of 33.6 newton-meters, equivalent to 3.4 kg meters.[16] An alternate study investigated isometric ER strength in overhead throwing athletes and nonathletes at 90 degrees of shoulder abduction and found mean ER strength of 9.39 kg and 7.90 kg, respectively.[13] In our study, patients in group B with high fatty infiltration of TM exhibited isokinetic strength significantly below these reported values at baseline (0.7 kg), whereas patients in group A with minimal fatty infiltration of TM did not have such a significant discrepancy (2.9 kg). Postoperative strength values improved significantly in both patient groups from their preoperative measurements and more closely approximated values in these other studies. This implies that LTTT can restore functional ER to the shoulder, validating previous biomechanical investigations demonstrating that LTTT results in restoration of ER.[9] It is noteworthy that the strength scores remain lower than those recorded in nonathletic adults, and this is also evident anecdotally where patients have described relative weakness despite the restorative ability to perform activities of daily living.

The overall rate of early failure in this study was relatively low. However, medium-to-long-term follow-up is needed to determine if LTTT is able to mitigate the longer-term deteriorative findings observed following LDTT. The alternative vector of pull driven by the LDTT has been hypothesized to lead to a higher risk of

progression to glenohumeral osteoarthritis in cases when the TM tendon has also been compromised. Mid-term results of LDTT for massive RC tears demonstrate progression to mild arthritis (Hamada grade 1 or 2) in a majority of patients (19/23, 82.6%) and advanced arthritis (Hamada grade 3 or 4) in 4/23 (17.4%) of patients.[19] Although these numbers are high, a general lack of long-term studies or comparative LTTT studies precludes a conclusion as to whether this is secondary to the transfer itself or due to the natural history of the underlying pathology.

Limitations of this study include the inability to monitor patient adherence to physiotherapy protocols and instructions, which may affect final outcomes. In addition, many patients demonstrated concomitant pathology requiring a variety of interventions, including subscapularis repair, partial supraspinatus/infraspinatus repair, acromioplasty, biceps tenotomy or tenodesis, and/or capsular releases, which could not be controlled for. Lastly, the results described are of minimum 1 year and will need to be further monitored in medium- and long-term time frames.

Despite these limitations, strengths of this study include a regimented analysis of patient range of motion and strength by a research team, allowing for reproducibility of measurements between patients and along various time points. Additionally, all surgeries performed in this multicenter study were performed by two fellowship-trained surgeons who employ the same LTTT technique, reducing variability of patient outcomes secondary to experience, surgical technique, and provided postoperative rehabilitation protocols. Despite having a more limited patient population, this study represents the largest to date to investigate factors affecting outcomes in patients with tendon transfers, allowing our results to be generalized to this patient population.

Conclusion

LTTT in patients with massive irreparable RC tears results in improved patient-reported outcome measures, range of motion, and ER strength regardless of the level of fatty infiltration of TM. LTTT is therefore a suitable operative intervention for patients with massive irreparable posterosuperior RC tears and should be strongly considered as a primary salvage option in this patient population.

Disclaimers:

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References

1. Berhouet J, Collin P, Benkalfate T, Le Du C, Duparc F, Courage O, et al. Massive rotator cuff tears in patients younger than 65 years. Epidemiology and characteristics. Orthop Traumatol Surg Res 2009;95:S13-8. https://doi.org/10.1016/j.otsr.2009.03.006.
2. Chambers MM, Khan AZ, Namdari S. Teres minor muscle atrophy: Anatomy, patterns, and clinical manifestations. JBJS Rev 2022 Dec 1;10. https://doi.org/10.2106/JBJS.RVW.22.00130.
3. Costouros JG, Espinosa N, Schmid MR, Gerber C. Teres minor integrity predicts outcome of latissimus dorsi tendon transfer for irreparable rotator cuff tears. J Shoulder Elbow Surg 2007;16:727-34. https://doi.org/10.1016/j.jse.2007.02.128.
4. Elhassan BT, Alentorn-Geli E, Assenmacher AT, Wagner ER. Arthroscopic-assisted lower trapezius tendon transfer for massive irreparable posterior-superior rotator cuff tears: surgical technique. Arthrosc Tech 2016;5:e981-8. https://doi.org/10.1016/j.eats.2016.04.025.
5. Elhassan BT, Sanchez-Sotelo J, Wagner ER. Outcome of arthroscopically assisted lower trapezius transfer to reconstruct massive irreparable posterior-superior rotator cuff tears. J Shoulder Elbow Surg 2020;29:2135-42. https://doi.org/10.1016/j.jse.2020.02.018.
6. Fuchs B, Weishaupt D, Zanetti M, Hodler J, Gerber C. Fatty degeneration of the muscles of the rotator cuff: assessment by computed tomography versus magnetic resonance imaging. J Shoulder Elbow Surg 1999;8:599-605.
7. Gates DH, Walters LS, Cowley J, Wilken JM, Resnik L. Range of motion requirements for upper-limb activities of daily living. Am J Occup Ther 2016;70. https://doi.org/10.5014/ajot.2016.015487. 7001350010p1-7001350010p10.
8. Hanisch K, Holte MB, Hvass I, Wedderkopp N. Clinically relevant results of reverse total shoulder arthroplasty for patients younger than 65 years compared to the older patients. Arthroplasty 2021;3:30. https://doi.org/10.1186/s42836-021-00086-4.
9. Hartzler RU, Barlow JD, An K-N, Elhassan BT. Biomechanical effectiveness of different types of tendon transfers to the shoulder for external rotation. J Shoulder Elbow Surg 2012;21:1370-6. https://doi.org/10.1016/j.jse.2012.01.026.
10. Langer JS, Sueoka SS, Wang AA. The importance of shoulder external rotation in activities of daily living: improving outcomes in traumatic brachial plexus palsy. J Hand Surg Am 2012;37:1430-6. https://doi.org/10.1016/j.jhsa.2012.04.011.
11. Minagawa H, Yamamoto N, Abe H, Fukuda M, Seki N, Kikuchi K, et al. Prevalence of symptomatic and asymptomatic rotator cuff tears in the general population: from mass-screening in one village. J Orthop 2013;10:8-12. https://doi.org/10.1016/j.jor.2013.01.008.
12. Namdari S, Yagnik G, Ebaugh DD, Nagda S, Ramsey ML, Williams GR, et al. Defining functional shoulder range of motion for activities of daily living. J Shoulder Elbow Surg 2012;21:1177-83. https://doi.org/10.1016/j.jse.2011.07.032.
13. Nodehi-Moghadam A, Nasrin N, Kharazmi A, Eskandari Z. A comparative study on shoulder rotational strength, range of motion and Proprioception between the throwing athletes and non-athletic Persons. Asian J Sports Med 2013;4:34-40. https://doi.org/10.5812/asjsm.34528.
14. Omid R, Heckmann N, Wang L, McGarry MH, Vangsness CT, Lee TQ. Biomechanical comparison between the trapezius transfer and latissimus transfer for irreparable posterosuperior rotator cuff tears. J Shoulder Elbow Surg 2015;24:1635-43. https://doi.org/10.1016/j.jse.2015.02.008.
15. Otto RJ, Clark RE, Frankle MA. Reverse shoulder arthroplasty in patients younger than 55 years: 2- to 12-year follow-up. J Shoulder Elbow Surg 2017;26:792-7. https://doi.org/10.1016/j.jse.2016.09.051.
16. Roy J-S, Macdermid JC, Boyd KU, Faber KJ, Drosdowech D, Athwal GS. Rotational strength, range of motion, and function in people with unaffected shoulders from various stages of life. Sports Med Arthrosc Rehabil Ther Technol 2009;1:4. https://doi.org/10.1186/1758-2555-1-4.
17. Schumaier A, Kovacevic D, Schmidt C, Green A, Rokito A, Jobin C, et al. Defining massive rotator cuff tears: a Delphi consensus study. J Shoulder Elbow Surg 2020;29:674-80. https://doi.org/10.1016/j.jse.2019.10.024.
18. Smith J, Padgett DJ, Dahm DL, Kaufman KR, Harrington SP, Morrow DA, et al. Electromyographic activity in the immobilized shoulder girdle musculature during contralateral upper limb movements. J Shoulder Elbow Surg 2004;13:583-8. https://doi.org/10.1016/j.jse.2004.03.010.
19. Suh D, Ji J-H, Tankshali K, Kim E-S. Mid-term clinical and Radiological outcomes of latissimus dorsi tendon transfer in massive rotator cuff tears. Clin Shoulder Elb 2019;22:220-6. https://doi.org/10.5397/cise.2019.22.4.220.
20. Thigpen CA, Shanley E, Momaya AM, Kissenberth MJ, Tolan SJ, Tokish JM, et al. Validity and responsiveness of the single Alpha-numeric evaluation for shoulder patients. Am J Sports Med 2018;46:3480-5. https://doi.org/10.1177/0363546518807924.
21. Uga D, Endo Y, Nakazawa R, Sakamoto M. Electromyographic analysis of the infraspinatus and scapular stabilizing muscles during isometric shoulder external rotation at various shoulder elevation angles. J Phys Ther Sci 2016;28:154-8. https://doi.org/10.1589/jpts.28.154.
22. Warner JJ, Parsons IM. Latissimus dorsi tendon transfer: a comparative analysis of primary and salvage reconstruction of massive, irreparable rotator cuff tears. J Shoulder Elbow Surg 2001;10:514-21.
23. Woodmass JM, Wagner ER, Borque KA, Chang MJ, Welp KM, Warner JJP. Superior capsule reconstruction using dermal allograft: early outcomes and survival. J Shoulder Elbow Surg 2019;28:S100-9. https://doi.org/10.1016/j.jse.2019.04.011.
24. Woodmass JM, Wagner ER, Chang MJ, Welp KM, Grubhofer F, Higgins LD, et al. Arthroscopic lower trapezius tendon transfer provides equivalent outcomes to latissimus dorsi transfer in the treatment of massive posterosuperior rotator cuff tears. J ISAKOS 2020;5:269-74. https://doi.org/10.1136/jisakos-2019-000341.