A Review of the Biomechanical and Functional Changes in the Shoulder following Transfer of the Latissimus Dorsi Muscles

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Summary: The latissimus dorsi muscle is among the most commonly used muscle flaps because it has broad versatility and is generally believed to result in minimal donor-site morbidity. However, the normal physiology of the shoulder girdle depends on the function of this muscle. Therefore, we have undertaken this review of the literature to examine the issue of biomechanical and functional changes of the shoulder that occur with transfer of the latissimus dorsi muscle and to determine whether these changes result in deficits in normal function. A review of the literature pertaining to all aspects of the latissimus muscle and shoulder function following muscle transfer was conducted. The latissimus muscle functions in extension, adduction, and internal and external rotation. After the transfer of the muscle there are deficits in extension and adduction. These deficits result in a faster rate of fatigue during activities in which the arms are extended over the head, such as ladder climbing and swimming. In addition, there is no decrease in range of shoulder motion. (*Plast. Reconstr. Surg.* 115: 2070, 2005.)

The use of muscle flaps to facilitate the transfer of soft tissue is one of the pillars of reconstructive surgery. The latissimus dorsi muscle is among the most commonly used muscle flaps because it has broad versatility and is generally believed to result in minimal donor-site morbidity. However, the normal physiology of the shoulder girdle depends on the function of this muscle. Thus, the questions are, are there biomechanical changes resulting from the loss of this muscle, and do these changes translate into a significant deficit in normal function? Perhaps most importantly, do these changes lead to interference with daily activities? We have undertaken this review of the literature to examine the issue of biomechanical and functional changes of the shoulder that occur with transfer of the latissimus dorsi muscle. In addition to any measurable changes, we were particularly interested in the clinical implications and how one should advise a patient considering these options.

Anatomy and Physiology

The latissimus dorsi muscle is one of 26 muscles that make up the complex shoulder joint.[1] Its broad origin arises as an aponeurosis from the lower thoracic and lumbar vertebra, sacrum, and iliac crest. As the muscle spans the back heading toward the shoulder, several small slips of origin may arise from the lower four ribs.[2] Crossing the scapula, the latissimus joins with the teres major muscle; it then wraps around the teres major as it traverses the axillary space, creating the posterior axillary fold. The muscle then inserts onto the anteromedial aspect of the humerus along the crest and floor of the bicipital or intertubercular groove, just lateral to the teres major muscle.[3]

Innervated by the thoracodorsal nerve (C6 to C8), the latissimus muscle acts on the humerus in medial rotation, adduction, shoulder

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extension, depressing of the raised arm, and downward rotation of the scapula. These functions are possible through the synergistic actions of the latissimus with six other muscles in which the teres major muscle is the principal component (Table I).[4] Although it is only one component of this seven-muscle unit, the latissimus is one of the most powerful of these muscles.[5]

Unfortunately, because of the number of muscles and complexity of vectors involved in each shoulder motion, it is difficult to quantify a specific muscle's exact contribution to a given movement. However, by studying anatomic features of each muscle and certain actions, such as torque, the approximate contribution of the latissimus muscle to shoulder motion can be appreciated. Therefore, the deficits created by its loss can be estimated. To begin with, the potential force generated by a muscle is based on its effective size, which is determined by its physiologic cross-section. This is calculated by measuring the volume of the muscle and dividing by the muscle fiber length. The value for each shoulder muscle has been previously calculated, and the latissimus muscles can generate a significant amount of force.[5] Second, when the working capacity of the shoulder is examined, we find that a relative balance exists between flexor and extensor torques. Ivey et al.[6] demonstrated these relationships in the shoulder using variable-resistance isokinetic devices. They found the following torque ratios: flexion-extension, 4:5; abduction-adduction, 1:2; and internal-external rotation, 3:2. Upon removal of the muscle, motions involving the latissimus should experience a change in these torque ratios, to a degree, based on the relative contribution of the latissimus to each movement.

TABLE I
Latissimus Dorsi Functions and Substitute Muscles

Function	Substitute Muscle
Medial rotation	Latissimus dorsi
	Pectoralis major
	Teres major
	Subscapularis
Backward extension	Latissimus dorsi
	Teres major
	Deltoid
Adduction	Latissimus dorsi
	Pectoralis major
	Coraco brachialis
	Teres major
	Teres minor
Depress raised arm	Latissimus dorsi
	Pectoralis major
	Teres major
Accessory cough and squeeze	All chest wall muscles

Reprinted from McCraw, J. B., Penix, J. O., and Baker, J. W. Repair of major defects of the chest wall and spine with the latissimus dorsi myocutaneous flap. *Plast. Reconstr. Surg.* 62: 197, 1978.

LITERATURE

The latissimus dorsi flap was originally described by Tansini in 1906 to cover mastectomy defects.[7] The flap fell out of favor until 1976, when Olivari[8] redescribed it. Since that time, it has become one of the workhorses for coverage of soft-tissue defects throughout the body. Surprisingly though, there have been few controlled studies to examine the biomechanical and functional changes that result from removing the latissimus muscle from the shoulder unit. This may be because early reports describing the use of the latissimus stated subjectively that shoulder function was unchanged.[4,8–10] It should be noted that some authors did state that disability could occur in activities that require strong shoulder adduction,[11,12] although none of these observations were verified by objective assessment.

It was not until 1985 that Laitung and Peck[13] examined shoulder adduction in 19 patients 2 months to 4 years after an operation in which the latissimus was removed and used as a free flap. With arms at 90 degrees of abduction, they utilized a Salter spring balance to examine adduction strength. The authors determined that adduction strength was not affected, but that scar contracture and loss of range of motion did occur. They concluded that latissimus muscle transfer did not affect arm adduction strength, and that therefore shoulder function was not affected.

In another study, Russell et al.[14] set out to determine the extent of functional deficit following the use of the latissimus muscle for reconstructive purposes. Twenty-four patients, 9 to 65 years of age, were studied 3 to 24 months after pedicled or free latissimus muscle transfer. Among other things, they attempted to examine the strength and range of motion of all shoulder and trunk muscles involved in shoulder motion. No instrument testing was utilized, and no attempt was made to standardize the group. The authors determined that the operated shoulder was up to 34 percent weaker than the nonoperated side in 73 percent of patients, and that some patients demonstrated a decreased range of motion following muscle transfer. Unfortunately, because each muscle group was not isolated, a conclusion concerning the specific actions of the latissimus muscle could not be drawn.

Since that time, several significant studies have examined the full extent of shoulder function following latissimus transfer.[15–17] Brumback et al.[15] examined the dominant and nondominant shoulders of 17 patients, 22 to 96 months after free muscle transfer. These patients were compared with 17 healthy volunteers. Patients were questioned regarding daily activities and were evaluated for scar quality, range of motion, and 19 different isometric, isotonic, and isokinetic strength tests. In this well-conducted study, the authors reported that none of the patients noted any change in the ability to perform activities of daily living or had to modify sports-related activities because of shoulder function. Only one patient described soreness of the donor shoulder following work performed with arms over the head. Also, passive range of motion was not reduced in these patients. Instrument testing focused only on shoulder actions in which the latissimus was involved: adduction, internal rotation, external rotation, and pushdown. The authors concluded that only when the arms are held in 60 degrees of flexion is forced extension weaker than controls but that there is no loss of range of motion or interference with daily activities.

In 1995, Fraulin et al.[16] reexamined this issue but focused on the change in muscle power (peak torque) and endurance (work). They evaluated 10 men and 16 women, 1.2 to 7.7 years after pedicled (women) or free (men) latissimus transfer against 15 controls (six men, nine women). Fifteen of the 26 patients reported difficulty with at least one activity since surgery. But only four complained of greater than 10 activities in which they had difficulty since surgery. Most of these activities involved working with the arm above the head. The authors concluded that women who underwent a unilateral pedicled latissimus transfer showed a deficit of power and endurance in shoulder extension and adduction as well as three work-simulated activities: ladder climbing, overhead painting, and pushing up from a chair. They further concluded that men who had previously undergone a free vascularized latissimus transfer showed a deficit in power and endurance in shoulder extension and adduction but no work-simulated activities.

Discussion

The use of the latissimus dorsi muscle for reconstruction, in particular breast reconstruction, has become common in plastic surgery. Advising patients on different reconstructive options requires educating them on the pros and cons of each method, not just in terms of the recipient site but the donor site as well because patients will have their own reasons for choosing a particular reconstruction. Therefore, it is necessary for the surgeon to have a thorough understanding of all aspects of the latissimus flap, especially the functional changes that can occur.

Despite the paucity of literature examining the biomechanics of the shoulder following removal of the latissimus muscle, there appears to be enough information to arrive at some conclusions. First, there are definite biomechanical changes that occur in the shoulder girdle following latissimus muscle transfer. This seems obvious when one considers the large size and biomechanical input that the latissimus provides to the overall shoulder functions of extension, adduction, and internal and external rotation. However, despite the normally significant power that the latissimus provides, the changes that result, including weakness of extension and adduction, appear to be less than one may expect. In fact, it is not a loss of power that will be noticed but the more rapid onset of fatigue during prolonged activities involving these motions that will be appreciated. Consequently, activities that involve these motions, such as swimming, ladder climbing, overhead painting, or pushing up from a chair, will be more strenuous and lead to muscle fatigue sooner.

So why doesn't the loss of such a major component of the shoulder lead to a more significant deficit? There are six other muscles of the shoulder girdle that act in the actions of extension, adduction, and internal and external rotation. Most authors agree that the most significant of these muscles is the teres major. With the loss of the latissimus, the synergistic action of the teres major muscle leads to muscle hypertrophy, thus compensating for the loss of the latissimus function. Over time any functional deficit will lessen, and normal function should be regained.[13–15]

Second, range of motion, both active and passive, are for the most part unchanged following the operation. Patients often feel restricted motion following the operation, which in turn can be perceived as weakness. However, in the immediate postoperative period one can reasonably attribute this to skin tightness resulting from the dissection or removal of a large skin paddle or significant amount of subcutaneous tissue, such as in the extended latissimus flap. As the scarring softens, patients may continue to appreciate the tightness at the surgical site, but the range of motion and perceived weakness will abate.

Finally, the most important aspect in advising patients is the effect that the operation will have on daily activities. In the immediate postoperative period, patients should expect to limit ipsilateral shoulder movement. However, by 2 to 3 weeks, patients should be using full range of motion. The amount of time for the teres major muscle to fully take over the function of the latissimus may take 6 to 12 months. Patients should be advised to perform extension and adduction exercises to speed this recovery.

Conclusions

The latissimus muscle is highly versatile and is used frequently in reconstruction. After muscle transfer, patients can expect deficits in extension and adduction. This is manifested by a faster rate of fatigue while performing tasks such as ladder climbing, swimming, and pushing up from a chair.

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