AJSM PreView, published on August 29, 2008 as doi:10.1177/0363546508322479

The Effect of Neuromuscular Electrical Stimulation of the Infraspinatus on Shoulder External Rotation Force Production After Rotator Cuff Repair Surgery

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Background: Muscle weakness, particularly of shoulder external rotation, is common after rotator cuff repair surgery. Neuromuscular electrical stimulation has been shown to be an effective adjunct in the enhancement of muscle recruitment.

Hypothesis: Shoulder external rotation peak force can be enhanced by neuromuscular electrical stimulation after rotator cuff repair surgery.

Study Design: Controlled laboratory study.

Methods: Thirty-nine patients (20 men, 19 women) who had undergone rotator cuff repair surgery were tested a mean of 10.5 days after surgery. Testing consisted of placing patients supine with the shoulder in 45° of abduction, neutral rotation, and 15° of horizontal adduction. Neuromuscular electrical stimulation was applied to the infraspinatus muscle belly and inferior to the spine of the scapula. Placement was confirmed by palpating the muscle during a resisted isometric contraction of the external rotators. Patients performed 3 isometric shoulder external rotation contractions with and without neuromuscular electrical stimulation, each with a 5-second hold against a handheld dynamometer. Neuromuscular electrical stimulation was applied at maximal intensity within comfort at 50 pulses per second, symmetrical waveform, and a 1-second ramp time. The 3 trials under each condition were recorded, and an average was taken. The order of testing was randomized for each patient tested. A paired samples t test was used to determine significant differences between conditions ($P < .05$). Each group was also divided based on age, rotator cuff tear size, number of days postoperative, and neuromuscular electrical stimulation intensity. Analysis of variance models were used to determine the influence of these variables on external rotation force production ($P < .05$).

Results: Peak force production was significantly greater ($P < .001$) when tested with neuromuscular electrical stimulation (3.75 kg) as opposed to without neuromuscular electrical stimulation (3.08 kg) for all groups tested. There was no significant difference based on the size of the tear, age of the patient, number of days after surgery, or level of neuromuscular electrical stimulation intensity.

Conclusion: Peak shoulder external rotation force was significantly increased by 22% when tested with neuromuscular electrical stimulation after rotator cuff repair surgery. Neuromuscular electrical stimulation significantly increased force production regardless of the age of the patient, size of the tear, intensity of the current, or the number of days postoperative.

Clinical Relevance: Neuromuscular electrical stimulation may be used concomitantly with exercises to enhance the amount of force production and potentially minimize the inhibition of the rotator cuff after repair surgery.

Keywords: shoulder; glenohumeral; rehabilitation; exercise; rotator cuff

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One or more of the authors has declared a potential conflict of interest: Kevin E. Wilk and Michael M. Reinold received a fee for organizing an educational program with EMPI which is the device used in this study.

The American Journal of Sports Medicine, Vol. X, No. X
DOI: 10.1177/0363546508322479

Rotator cuff repair surgery is a commonly performed surgical operation in patients who have functional limitation due to tendon injuries. Surgical techniques have evolved that are less invasive, and therefore less disruptive, to the surrounding glenohumeral soft tissue and musculature. Thus, the patient is able to progress postoperatively with less discomfort and functional limitations from pain and muscle inhibition. The ultimate postoperative goals for the rehabilitation specialist, in addition to protecting the integrity of the repair, are to diminish pain and improve strength and range of motion (ROM). Achieving these goals will aid in regaining function of the limb and a return to premorbid activities of daily living. Frequently, loss of function is related to muscle weakness, inhibition, and imbalance in rotator cuff strength, particularly of the external rotators, after these procedures.[13] Previous studies have shown a loss of external rotation strength that is persistent up to 1 year after the surgery. This rotator cuff inefficiency may result in a loss of dynamic stability of the glenohumeral joint and a delay in the ability to elevate the arm without a compensatory "shrug."[12,23] Consequently, the emphasis of the postoperative rehabilitation is to regain strength, minimize muscular inhibition, and initiate voluntary control of the rotator cuff to maintain a centered humeral head within the glenoid during upper body movement patterns.

Neuromuscular electrical stimulation (NMES) has been recommended as an adjunct treatment for neuromuscular reeducation and strengthening due to the muscle inhibition resulting from postoperative pain and joint effusion.[††] Numerous studies have shown that NMES enhances force (torque) production, muscle recruitment, and ultimately results in improved gait and a quicker recovery of function.[6,9,16,17,18] This has been demonstrated in previous studies when compared with volitional exercise without NMES after anterior cruciate ligament (ACL) reconstruction and total knee arthroplasty (TKA).[8,11,20] Although NMES may be more effective in increasing isometric strength of the muscle, a carryover effect may enhance the other types of muscle contractions (concentric, eccentric), which may lead to improved functional gains for the patient.[10]

The use of NMES for the shoulder has received little attention in orthopaedic communities, with research limited to the rehabilitation of patients after cerebral vascular accidents.[3,7] Although the effects of NMES have been documented after surgical procedures of the knee, there is little evidence of efficacy for the use of NMES of the rotator cuff after shoulder surgery. Therefore, the objective of this study was to compare the peak force produced by the infraspinatus during an isometric shoulder contraction with and without the use of NMES after rotator cuff repair surgery. The purpose of this study is to identify if the application of NMES can be used concomitantly with rehabilitation exercises to recruit more muscular force and potentially result in greater strength gains postoperatively.

[††]References 2, 5, 6, 8, 9, 11, 16-20, 24, 25.

TABLE 1
Patient Demographics

N = 39	20 males, 19 females
Age, y (range)	54 (23-76)
Height, m	1.72
Weight, kg	85.2
Surgery type, arthroscopic/mini open	37/2
Average tear size, cm	2.9

METHODS

Participants

Thirty-nine patients (20 male, 19 female) who had undergone rotator cuff repair surgery of the supraspinatus tendon participated in the study. All were tested at a mean of 10.5 ± 7.1 days after surgery (range, 2-19 days). Mean age of participants was 54 ± 3.9 years old. Thirty-seven of the patients underwent an arthroscopic procedure, while 2 had a mini-open procedure. Full demographic data on the participants are shown in Table 1. Each patient signed an informed consent, and the rights of each were protected. The research protocol was approved by the Institutional Review Board of the American Sports Medicine Institute.

Testing Procedure

Patients were placed supine with the shoulder in 45° of abduction, neutral rotation, and 15° of horizontal adduction. This was achieved by using a bolster under the distal humerus to maintain consistent placement. Electrical stimulation was applied to the infraspinatus muscle by means of an EMPI 300 PV unit (EMPI Corporation, St Paul, Minnesota). The location of pad placement was performed according to Basmajian and De Luca[1] and De Duca and Forrest.[4] Pad placement was assisted by palpation and visual localization of the muscle during a resisted isometric contraction (Figure 1).

The electrical stimulation amplitude was applied to the patient's maximal perceived tolerance. Testing was discontinued if the patient experienced discomfort. The device was set at a frequency of 50 pulses per second, asymmetrical waveform, pulse length of 300 microseconds, and a 1-second ramp time.

Patients performed 3 isometric contractions of external rotation for 5 seconds into a handheld dynamometer (MicroFet; Hoggan Health Industries, Draper, Utah) with and without the concomitant application of NMES. The dynamometer was placed at the patient's wrist, just proximal to the ulnar styloid process (Figure 2). The order of testing condition was randomized for each person. The 3 trials under each condition were averaged and recorded for analysis. The same examiner (L.C.M.) was used for all testing to maintain consistency and maximize intertester reliability.

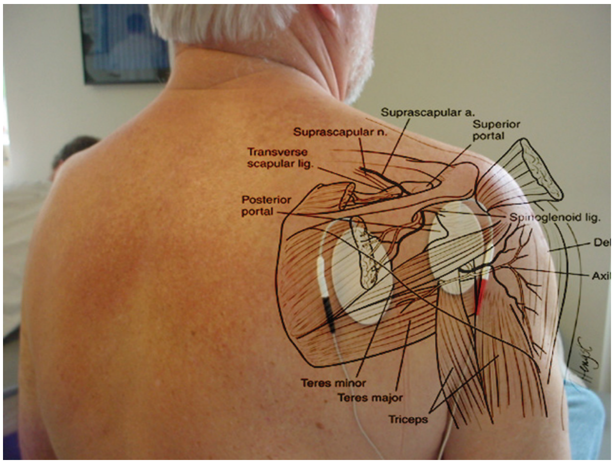

Figure 1. Pad placement along the muscle belly of the infraspinatus.

Figure 2. Testing position for recording external rotation force production with and without NMES application.

Statistical Analysis

A paired samples *t* test was used to determine if a significant difference was present between the groups with and without NMES applied ($P < .05$). The cohort was also divided into comparison groups based on age (<45 years old, 45-59 years old, >60 years old), gender, rotator cuff tear size (<2 cm, 2-4 cm, >4 cm), number of days postoperative after surgery (<8 days, ≥8 days), and intensity of the NMES (<20 mA, >20 mA). Analysis of variance (ANOVA) models were used to determine the influence of these variables on force production ($P < .05$).

RESULTS

No patients reported any difficulty or discomfort during testing. Peak force production showed a statistically significant increase in force production by 22% ($P < .001$) in the group with electrical stimulation (3.75 kg) applied to the infraspinatus compared with the control group who did not receive the electrical stimulation (3.08 kg). There was no statistically significant difference between groups when broken down by gender ($P = .66$), age ($P = .17$), days after surgery ($P = .06$), size of the tear ($P = .16$), or electrical stimulation intensity setting ($P = .50$) (Table 2).

DISCUSSION

It is well documented that human musculature becomes inhibited after surgical procedures due to pain stimulus[9] and joint effusion.[5,19,21,22,24,25] Therefore, efforts to prevent the deleterious effects of pain, effusion, and muscle inhibition are often recommended early in the rehabilitation process to restore muscle strength and return the patient back to functional activities and maximize outcomes.

The current study demonstrates that the application of NMES to the infraspinatus after rotator cuff repair surgery allows a significant increase of volitional muscle force production during external rotation. These results are similar to the results of past authors, who showed similar increases in force production of the quadriceps muscle after ACL reconstruction[6,8,16-18] and TKA.[8,11,20]

Furthermore, the use of NMES significantly increased force production, regardless of the age of the patient, gender, size of tear, and number of days after surgery. Furthermore, patients who could not tolerate high levels of NMES also showed increased force production, regardless of the level of NMES intensity. This may allow the clinician to apply the NMES in a manner that ensures patient safety and comfort, while retaining effectiveness. No deleterious effects were observed during the testing procedure, which demonstrates the safety and efficacy of the application of NMES in groups of patients at a mean of 10.5 days postoperative.

This study is the first to look at the effects of NMES on force production in the rotator cuff repair population. On the basis of the results of this study, the authors recommend that NMES be applied after rotator cuff repair surgery to maximize the amount of infraspinatus force production. While the current study demonstrated an increase in force production during 1 application of NMES, past studies after ACL reconstruction and total knee arthroplasty have demonstrated a carryover effect of NMES use on improved gait and functional outcomes.[8,11,20] Neuromuscular electrical stimulation may be applied concomitantly to maximize force production during standard rehabilitation exercises, such as isometric, isotonic tubing, and dumbbell exercises, as well as during manual resistance and stabilization techniques. By improving external rotation force production, a vital component to dynamic stabilization of the glenohumeral joint,[14,15] the patient may be able to achieve improved active elevation by enhancing the force couple balance of the external and internal rotators of the rotator cuff. This force couple functions synchronously to center the humeral head during active arm elevation without superior humeral head migration and a subsequent shoulder "shrug" sign. This may ultimately

TABLE 2
Mean (± SD) External Rotation Force Producing With and Without Neuromuscular Electrical Stimulation

	n	Force Production With NMES, kg (±SD)	Force Production Without NMES (±SD)	*P* Value
Total results	39	3.75 (±1.8)	3.08 (±1.6)	<.001
Gender				
Male	20	3.87 (±2.1)	3.19 (±1.8)	.66
Female	19	3.63 (±1.4)	2.97 (±1.22)	
Age, y				
<45	8	2.98 (±1.2)	2.56 (±1.2)	.167
45-59	13	4.54 (±2.5)	3.54 (±2.1)	
>60	18	3.53 (±1.2)	2.98 (±1.1)	
Days after surgery				
< 8	10	2.72 (±0.81)	2.29 (±0.75)	.06
≥ 8	29	4.10 (±1.9)	3.36 (±1.7)	
NMES setting				
≤20	29	3.81 (±1.9)	3.24 (±1.6)	.50
>20	10	3.57 (±1.5)	2.64 (±1.2)	
Size of tear, cm				
<2	8	3.47 (±1.3)	2.5 (±0.85)	.16
2-4	20	4.27 (±2.1)	3.65 (±1.8)	
>4	7	2.94 (±1.0)	2.35 (±0.56)	

NMES, neuromuscular electrical stimulation.

lead to improved functional gains and postoperative outcomes in the rotator cuff repair patient.

The use of NMES may be an effective technique after other surgical procedures such as superior labral anterior to posterior (SLAP) repairs, Bankart repairs, or simple subacromial decompressions. Nonoperative patients with dysfunction of the rotator cuff such as subacromial impingement or multidirectional instability may also benefit from NMES. Future research should attempt to document the efficacy of NMES in these patient populations as well.

In addition, we have shown that NMES effectively increases force production during one application. Future research is warranted to examine whether the use of NMES has an effect on continual strength gains and serve as a predictor of improved functional outcomes over time.

We chose to use 1 unblinded examiner (L.C.M.) to conduct all testing to maximize reliability. We do not believe bias was observed as the examiner measured the amount of isometric force that the patient could independently produce and had no effect on the amount of force produced.

CONCLUSION

Peak shoulder external rotation force was significantly increased by 22% when performed with NMES after rotator cuff repair surgery. These gains in force production were observed regardless of the patient's gender, age, size of tear, days postoperative, or intensity of the NMES. The rehabilitation specialist may consider using NMES as a safe and effective modality to improve external rotation force production during rehabilitation of rotator cuff repair patients.

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