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| Therapeutic Exercise for Muscular Deficits of the Shoulder Evidence Table | |
| Author/Year:  Oranchuk DJ, 20191 | **Purpose:** To detail the medium- to long-term adaptations of different types of isometric training on morphological, neurological, and performance variables.  **Design:** Systematic Review  **Subjects:** 26 research outputs acquired through MEDLINE, PubMed, SPORTDiscus, and CINAHL databases.  *Inclusion criteria*: full text available in English, peer-reviewed journal publication or doctoral dissertations, and the study compared two or more variations of isometric training  *Exclusion criteria:* conference papers/posters/presentations, focused on small joints or muscles such as fingers or toes, primary dependent variables related to cardiovascular health, including non-human subjects, in vitro, intervention period less than three weeks in duration, and including variables such as blood restriction, vibration, or electrical stimulation  **Intervention & Procedures:** All 26 studies clearly stated independent and dependent variables, and 10 included a non-exercise control group. The mean length of intervention was 8.4 ± 3.6 (range = 3‐14) weeks, with an average of 3.5 ± 0.96 (range = 2-7) sessions per week for an average of 28.6 ± 13.2 (range = 15 – 56) total training sessions. Interventions were volume-equated in 17/26 studies, while 10/26 studies included a non-exercise control group. Closed-chain movements were only utilized in two studies, whereas 23/26 utilized single-joint contractions. 10 studies examined the chronic (5-12 weeks) effects of isometric training at varying joint angles. 6 studies examined the effect of contraction intensity. Training variations outside of joint position or contraction intensity were also included which investigated the following: (a) intent of contraction which included “progressive” vs “rapid” and “explosive” vs “sustained” contractions, (b) total volume, (c) contraction duration, (d) rest period duration, and (e) periodization schemes.  **Outcomes/Results:** Measures of muscular size increased in 9 studies (5%‐19.7%, ES = 0.19‐1.23) by 0.84%/week and 0.043 ES/week. Maximal isometric force significantly increased in 14 studies (8%‐60.3%, ES = 0.34‐3.26) by 4.34%/week and 0.20 ES/week. Though the direct transfer of isometric resistance training to dynamic movements is questionable, physiological adaptations such as increased muscle mass and improved tendon qualities are beneficial in a variety of contexts. Producing and maintaining muscle mass with isometric resistance training can be beneficial in patients in which dynamic contractions is contraindicated. However, isometric resistance training should be performed in a way that most closely resembles the desired goal (i.e. angle of contraction most relating to activity). Also, sustained contractions generally offer similar or greater morphological adaptations than ballistic contractions. Findings suggest that isometric training intensity is not important when aiming to improve force production to alter muscle morphology.  **Limitations/Comments:** None of the studies included special populations such as patients with tendon disorders, high-performance athletes, or experienced resistance trainees. Also, very few of the included studies examined the effect of isometric training on dynamic performance, and only one utilized closed-chain or functional performance tasks in their testing batteries. Lastly, the large variety of independent and dependent variables resulted in less definitive conclusions secondary to extensive inter-study analysis. |
| Author/Year:  Wattanaprakornkul D, 20112 | **Purpose:** to comprehensively examine shoulder muscle activity during flexion in order to compare the activity levels and recruitment patterns of shoulder flexor, scapular lateral rotator and rotator cuff muscles.  **Design:** Observational Study  **Subjects:** 15 subjects (12 males; 3 females) with no shoulder symptoms for at least the previous two years and who have never sought treatment for shoulder pain. Participants were screened by a physical therapist to ensure full pain-free normal range of shoulder motion, normal scapulohumeral rhythm, and absence of pain during maximal isometric internal and external shoulder strength tests of their dominant shoulder.  **Intervention & Procedures:** Twelve shoulder muscle sites were investigated using a combination of surface and indwelling electrodes. Surface electrodes recorded activity in the upper trapezius, deltoid (anterior, middle, and posterior sections), and pectoralis major (sternoclavicular portion). Indwelling electrodes were inserted into the supraspinatus, infraspinatus, middle and lower trapezius, serratus anterior, latissimus dorsi, and subscapularis. The subject performed a sagittal plane flexion movement starting with the arm by the side moving to full range of shoulder flexion and then back to the arm by the side at a standardized speed. The task was performed with the shoulder in neutral rotation, the elbow in extension, and the forearm in med-rotation (thumb up) and completed in six seconds (3 second concentric, 3 second eccentric). The maximum load one rep max was determined. Two repetitions of the flexion movement were performed at no load, 20, and 60 percent of maximum load in random order. Percent maximal voluntary contraction of the twelve muscle sites was acquired via EMG.  **Outcomes/Results:** The anterior deltoid, pectoralis major, supraspinatus, infraspinatus, serratus anterior, and upper and lower trapezius were activated at similar moderate levels. The subscapularis was activated at low levels and significantly lower than supraspinatus and infraspinatus. Similar activity patterns were demonstrated in the muscles that produce flexion torque, laterally rotate the scapula, as well as supraspinatus and infraspinatus, and did not change as flexion load increased. Supraspinatus and anterior deltoid activity onset occurred at the same time and prior to movement of the limb at all loads with infraspinatus activity also occurring prior to movement onset at the medium and high load conditions only. Posterior rotator cuff muscles appear to be counterbalancing anterior translational forces produced during flexion, and the supraspinatus is one of the muscles that consistently initiates flexion.  **Limitations/Comments:** The study is limited to only flexion movements, is composed of a small sample size, and the sample recruitment method was not disclosed. Also, the study does not differentiate between muscles actually performing the flexion movement as opposed to contracting to stabilize and maintain a sagittal position. However, the study was able to demonstrate similar recruitment patterns in shoulder musculature to produce flexion across time despite level of load. |
| Author/Year:  Wattanaprakornkul D, 20113 | **Purpose:** To investigate direction-specific recruitment patterns of rotator cuff muscles during shoulder flexion and extension exercises  **Design:** Observational Study  **Subjects:** 15 subjects (10 male; 5 female) with normal dominant shoulder function with no pain in the previous two years  **Intervention & Procedures:** EMG activity was recorded from 9 shoulder muscles via surface electrodes (upper trapezius, middle deltoid, and pectoralis major) and indwelling electrodes (supraspinatus, infraspinatus, lower trapezius, serratus anterior, latissimus dorsi, and subscapularis). Flexion and extension exercises were performed in prone at 20%, 50%, and 70% of each participant’s maximal load. A repeated measures ANOVA was used to determine differences between exercises, muscles, and loads, while Pearson’s correlation analysis was used to relate mean EMG patterns.  **Outcomes/Results:** During extension, subscapularis and latissimus dorsi were activated at higher levels than during flexion. During flexion, supraspinatus, infraspinatus, deltoid, trapezius, and serratus anterior were more highly activated than during extension. The pattern of activity in each muscle did not vary with load. The rotator cuff muscles are recruited in a direction-specific manner to prevent potential antero-posterior humeral head translation caused by torque producing muscles.  **Limitations/Comments:** The sample size is small, and the subjects were not representative of the general public since they were recruited from a university campus. Placement of electrodes to specifically record from the anterior fibers of the deltoid, posterior fibers of the deltoid, and clavicular head of the pectoralis major would have enabled a more complete description of the activation of flexor and extensor torque producing muscles. |
| Author/Year:  Wickham J, 20104 | **Purpose:** To obtain EMG activity from a sample of healthy shoulders to allow a reference database to be developed and used for comparison with pathological shoulders.  **Design:** Observational Study  **Subjects:** 24 subjects (13 male; 11 female) aged between 18 and 37 years old with no known history of shoulder pathologies  **Intervention & Procedures:** Temporal and intensity shoulder muscle activation characteristics during a coronal plane abduction/adduction movement were evaluated in the dominant healthy shoulder. Surface and intramuscular fine wire electrodes recorded EMG activity from 15 shoulder muscles (anterior, middle, and posterior deltoid, upper, middle, and lower trapezius, subscapularis x 2, latissimus dorsi, pectoralis major, pectoralis minor, supraspinatus, infraspinatus, serratus anterior, and rhomboids) at 2000 Hz for 10 seconds while each subject performed 10 dynamic coronal plane abduction/adduction movements from 0 degrees to 166 degrees with a light dumbbell equal to 25% of abduction MVC at 90 degrees.  **Outcomes/Results:** Supraspinatus (-0.102 seconds before movement onset) initiated the movement with middle trapezius (-0.019 seconds) and middle deltoid (-0.014 seconds) also activated before the movement onset. Similar patterns were also found in the time of peak amplitude and %MVC with a pattern emerging where the prime movers (supraspinatus and middle deltoid) were among the first to reach peak amplitude or display the highest %MVC values.  **Limitations/Comments:** Occasionally, both surface and intramuscular electrodes become displaced during testing, resulting in incomplete data sets for some participants secondary to exclusion of data where electrodes were displaced. Some participants’ natural standing posture resulted in some muscles working hyper-tonically, creating a noisy baseline, thus, leading to the muscle working above 10% MVC intensity at the initiation of recording at times and an exclusion from the data set. Also, the sample size was small and composed of a volunteer set of participants which could affect the generalizability of the findings. |
| Author/Year:  Reed D, 20105 | **Purpose:** To determine if rotator cuff muscles activate more than other shoulder muscles during isometric shoulder adduction while also identifying if activation patterns are influenced by shoulder abduction angle or load.  **Design:** Within-participant repeated measures experimental study  **Subjects:** 15 subjects with no history of shoulder pain in the previous two years who had never sought treatment for shoulder pain  **Intervention & Procedures:** Participants performed an isometric adduction exercise at 30 degrees, 60 degrees, and 90 degrees abduction in the scapular plane and at 25%, 50%, 75%, and 100% load. During the exercises, a combination of indwelling and surface EMG recordings were taken from 11 shoulder muscles (supraspinatus, infraspinatus, subscapularis, pectoralis major, teres major, latissimus dorsi, rhomboid major, serratus anterior, lower trapezius, upper trapezius, and deltoid).  **Outcomes/Results:** At 100% load, mean rotator cuff activation levels were low (supraspinatus at 3% MVC, infraspinatus 27% MVC, and subscapularis 27%) and significantly less than the activation levels of rhomboid major (81% MVC), latissimus dorsi (103% MVC), and teres major (76% MVC) (F10,140 = 15.5, p < 0.01). No significant difference in activity levels of the rotator cuff muscles were recorded when isometric adduction was performed at 30 degrees, 60 degrees, or 90 degrees abduction (p > 0.89). Among the muscles activated above minimum levels (> 10% MVC), mean activation levels increased as load increased (F3,42 = 72.0, p < 0.01). Since isometric adduction in normal subjects does not produce moderate to high activation levels in any of the rotator cuff muscles tested, these results do not support the use of shoulder adduction to identify rotator cuff muscle dysfunction or strengthen the rotator cuff muscles.  **Limitations/Comments:** The recruitment of the sample was not disclosed, and the sample size was small; thus, generalizability is limited. Electrode placement of pectoralis major may not have been optimal to detect activity in the deeper sternal head which is more likely to be activated in adduction. |
| Author/Year:  Edwards PK, 20176 | **Purpose:** To review the current literature investigating EMG during rehabilitation exercises in normal shoulders and to identify exercises that meet a cut point of 15% MVIC or less and are unlikely to result in excessive loading in the early postoperative stages.  **Design:** Systematic Review  **Subjects:** 20 studies included through searches of MEDLINE via Ovid, Embase, CINAHL, SPORTDiscus, PubMed, and the Cochrane Library  *Inclusion Criteria:* used EMG as a primary tool to detect muscle activity in the rotator cuff during rehabilitation exercises, undertake EMG analysis of at least 1 rotator cuff muscle, minimum of 2 repetitions of each exercise performed that were specifically designed to load the rotator cuff or to rehabilitate and restore function following rotator cuff repair, and published in a peer-reviewed journal  *Exclusion Criteria:* sample including patients with a history of shoulder pathology, injury, or pain, mean age or upper age limit range above 50 years, studies with a specific aim to evaluate a clinical test, studies in which rotator cuff muscle activity was examined during activities such as occupational tasks, sporting tasks, or specific hand grips, individual exercises being studied, studies that did not normalize the EMG activity of exercises to an MVIC, studies that recorded supraspinatus activity via surface EMG, non-English studies, review articles, conference abstracts, non-peer-reviewed studies, case reports, opinion pieces, and articles for which full text was not available  **Intervention & Procedures:** Pooled mean MVICs were reported and classified as low (0%-15% MVIC), low to moderate (16%-20% MVIC), moderate (21%-40% MVIC), high (41%-60% MVIC), and very high (greater than 60% MVIC). 43 exercises spanning passive range of motion, active-assisted range of motion, and strengthening exercises were evaluated.  **Outcomes/Results:** Out of 13 active-assisted exercises, 9 were identified as suitable (15% MVIC or less) to load the supraspinatus and 10 as suitable to load the infraspinatus early after surgery. All exercises were placed in a theoretical continuum model, by which general recommendations could be made for prescription in patients post-rotator cuff repair. Most passive range of motion exercises demonstrated activation levels below the cutoff. Active-assisted exercises using the asymptomatic limb to move the operated limb generated a low level of activation in both the supraspinatus and infraspinatus, whereas active-assisted exercises using a bar or a pulley to elevate the operated limb tended to generate over 15% MVIC.  **Limitations/Comments:** Results are solely based on reported values from younger, healthy individuals performing selected rotator cuff exercises. Most of the EMG studies available used nonpathological shoulders to investigate cuff activation during rehabilitation exercises. Therefore, the results of this study may not be generalizable to symptomatic, pathological, or elder populations. |
| Author/Year:  Alizadehkhaiyat O, 20157 | **Purpose:** To investigate activation pattern of sixteen shoulder girdle muscles/muscle sub-regions during three common shoulder internal rotation exercises.  **Design:** Observational Study  **Subjects:** 30 healthy subjects (15 male; 15 female) with normal upper limb clinical examination and no history of upper limb painful conditions.  **Intervention & Procedures:** EMG was recorded from sixteen shoulder girdle muscles/muscle sub-regions (surface electrode: anterior, middle, and posterior deltoid, upper, middle, and lower trapezius, serratus anterior, teres major, upper and lower latissimus dorsi, upper and lower pectoralis major; fine wire electrodes: supraspinatus, infraspinatus, subscapularis, and rhomboid major) using a telemetric EMG system. Three internal rotation exercises (standing internal rotation at zero degrees and 90 degrees of abduction and internal rotation at Zero-Position [zero rotation of the humerus with arm elevated at 155 degrees in scapular plane and elastic resistance applied against internal rotation]) were studied. Twelve cycles of each exercise were performed using either a one kilogram dumbbell in hand (internal rotation at 0 and 90 degrees abduction) or an elastic band (internal rotation at Zero-Position) according to a metronome set at 60 beats per minute (each concentric and eccentric phase performed during one beat). A three minute rest period was given between each exercise. EMG maximal force in a standard position were recorded and compared using one-way repeated-measures ANOVA.  **Outcomes/Results:** Rotator cuff and deltoid muscles were highly activated during internal rotation at 90 degrees abduction. Latissimus dorsi demonstrated significantly higher activation during internal rotation at Zero-Position. Upper trapezius had the highest activation during internal rotation at Zero-Position, but middle and lower trapezius were activated at the highest during internal rotation at 90 degrees of abduction. The highest activation of the serratus anterior and rhomboid major occurred in internal rotation at Zero-Position and internal rotation at 90 degrees of abduction, respectively.  **Limitations/Comments:** The study utilized an EMG normalization method that is valid in comparing activity of each muscle across the internal rotation exercises (between-exercise comparison), but it may not be the preferred method for comparing activations between muscles (between-muscle comparison) as maximum force production during the task used for normalization does not necessarily produce a maximum activation in the muscles under investigation. Also, variable loads were not utilized which could have provided greater information regarding the contribution of each muscle. Another limitation lies with the testing of only asymptomatic subjects. |
| Author/Year:  Brumitt J, 20098 | **Purpose:** To review the activity of trunk musculature during upper extremity exercise and present a rehabilitation exercise progression for the shoulder girdle that integrates core muscle strengthening and activation.  **Design:** Clinical Commentary  **Subjects:** A total of 28 resources were compiled and summarized to compose this commentary.  **Intervention & Procedures:** The authors conveyed initial shoulder rehabilitation exercises throughout scapular and glenohumeral musculature to promote normal kinematics and neural control. The authors proposed addressing proximal dysfunction in the kinetic chain first by targeting scapular dyskinesis. As scapular mechanics improve, rotator cuff and scapular strength deficits should be addressed. As strength increases, sport specific movements should be incorporated. The authors also proposed to incorporate trunk musculature exercises in conjunction with glenohumeral exercises in order to prepare the athlete for more advanced functional exercises. Identifying core weakness in athletes is important since dysfunction within the kinetic chain will affect how forces are generated, summated, or transferred from proximal segments to the upper extremity and possibly resulting in an upper extremity overuse injury. The authors then provide examples of combined shoulder and core exercises.  **Outcomes/Results:** The inclusion of integrated core and shoulder exercises may help to bridge the gap between the initial rehabilitation exercises and later functional rehabilitation exercises.  **Limitations/Comments:** The article does not disclose the methods of obtaining information; thus, biased information acquisition could have occurred. The information conveyed is non-exhaustive and may be dated. There is limited research to support the muscular activation levels of the rotator cuff and scapular muscles within the proposed exercise postures. |

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