1: J Strength Cond Res. 2005 Feb;19(1):193-201.

Allen Press, Inc. Full-Text

Trunk muscle electromyographic activity with unstable and unilateral exercises.

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The purpose of this cross-sectional study was to evaluate the effect of unstable and unilateral resistance exercises on trunk muscle activation. Eleven subjects (6 men and 5 women) between 20 and 45 years of age participated. Six trunk exercises, as well as unilateral and bilateral shoulder and chest presses against resistance, were performed on stable (bench) and unstable (Swiss ball) bases. Electromyographic activity of the upper lumbar, lumbosacral erector spinae, and lower-abdominal muscles were monitored. Instability generated greater activation of the lower-abdominal stabilizer musculature (27.9%) with the trunk exercises and all trunk stabilizers (37.7-54.3%) with the chest press. There was no effect of instability on the shoulder press. Unilateral shoulder press produced greater activation of the back stabilizers, and unilateral chest press resulted in higher activation of all trunk stabilizers, when compared with bilateral presses. Regardless of stability, the superman exercise was the most effective trunk-stabilizer exercise for back-stabilizer activation, whereas the side bridge was the optimal exercise for lower-abdominal muscle activation. Thus, the most effective means for trunk strengthening should involve back or abdominal exercises with unstable bases. Furthermore, trunk strengthening can also occur when performing resistance exercises for the limbs, if the exercises are performed unilaterally.

PMID: 15705034 [PubMed - indexed for MEDLINE]

Electromyogr Clin Neurophysiol. 2004 Jan-Feb;44(1):57-64.

Electromyographic activity of selected trunk muscles during stabilization exercises using a gym ball.

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Trunk stabilization is very important for the injured lower back. The use of a gym ball, the surface of which is labile, is becoming more popular for strengthening the trunk muscles and challenging the motor control system in trunk stabilization exercises. However, little is known about the activity of the trunk muscles during such exercises. The purpose of this study was to compare the electromyographic (EMG) activity of the trunk muscles during seven stabilization exercises using a gym ball. Eleven healthy men (19.9 +/- 1.8 years old) without low back pain volunteered to participate in the study. Bipolar surface electrodes were attached to the right side of the upper and lower rectus abdominis, the obliquus externus abdominis and the upper and lower back extensor muscles. EMG signals were recorded during seven types of stabilization exercises using a gym ball and normalized to maximal voluntary contraction (% MVC). A two-way analysis of variance (ANOVA) was performed on % MVC from each task for each of the five trunk muscle sites ($p < 0.05$). Push-up exercise, supporting with both hands on the gym ball and toes on the floor in prone position, resulted in the highest activity of all abdominal muscles, and an exercise of the lifting the gym ball up, holding it actively between both legs with both knees flexed in supine position resulted in the lowest. Lifting up of the pelvis in a bridged position exercise, supporting the head with the gym ball and with the feet on the floor in supine position, resulted in higher muscle activity of the back extensor muscles than another exercise. It is very important for physical therapists to make clear the purpose of the trunk stabilization exercises, because different kinds of exercises with the gym ball demand various levels of muscular activity and use of various parts of the trunk muscles.

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Arch Phys Med Rehabil. 2005 Feb;86(2):242-9.

ELSEVIER FULL-TEXT ARTICLE

Core stability exercises on and off a Swiss ball.

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OBJECTIVES: To assess lumbopelvic muscle activity during different core stability exercises on and off a Swiss ball. DESIGN: Prospective comparison study. SETTING: Research laboratory. PARTICIPANTS: Eight healthy volunteers from a university population. INTERVENTION: Subjects performed 4 exercises on and off a Swiss ball: inclined press-up, upper body roll-out, single-leg hold, and quadruped exercise. MAIN OUTCOME MEASURES: Surface electromyography from selected lumbopelvic muscles, normalized to maximum voluntary isometric contraction, and median frequency analysis of electromyography power spectrum. Visual analog scale for perception of task difficulty. RESULTS: There was a significant increase in the activation of the rectus abdominus with performance of the single-leg hold and at the top of the press-up on the Swiss ball. This led to changes in the relation between the activation levels of the lumbopelvic muscles measured. CONCLUSIONS: Although there was evidence to suggest that the Swiss ball provides a training stimulus for the rectus abdominus, the relevance of this change to core stability training requires further research because the focus of stabilization training is on minimizing rectus abdominus activity. Further support has also been provided about the quality of the quadruped exercise for core stability.

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J Strength Cond Res. 2005 Feb;19(1):193-201.

Trunk muscle electromyographic activity with unstable and unilateral exercises.

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PMID: 15705034 [PubMed - indexed for MEDLINE]

J Strength Cond Res. 2004 Aug;18(3):637-40.

Maintenance of EMG activity and loss of force output with instability.

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Swiss Balls used as a platform for training provide an unstable environment for force production. The objective of this study was to measure differences in force output and electromyographic (EMG) activity of the pectoralis major, anterior deltoid, triceps, latissimus dorsi, and rectus abdominus for isometric and dynamic contractions under stable and unstable conditions. Ten healthy male subjects performed a chest press while supported on a bench or a ball. Unstable isometric maximum force output was 59.6% less than under stable conditions. However, there were no significant differences in overall EMG activity between the stable and unstable protocols. Greater EMG activity was detected with concentric vs. eccentric or isometric contractions. The decreased balance associated with resistance training on an unstable surface may force limb musculature to play a greater role in joint stability. The diminished force output suggests that the overload stresses required for strength training necessitate the inclusion of resistance training on stable surfaces.

Publication Types:

- Clinical Trial

PMID: 15320684 [PubMed - indexed for MEDLINE

J Strength Cond Res. 2004 Aug;18(3):522-8.

The effect of short-term Swiss ball training on core stability and running economy.

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The purpose of this study was to investigate the effect of a short-term Swiss ball training on core stability and running economy. Eighteen young male athletes (15.5 +/- 1.4 years; 62.5 +/- 4.7 kg; sigma9 skinfolds 78.9 +/- 28.2 mm; VO2max 55.3 +/- 5.7 ml.kg(-1).min(-1)) were divided into a control (n = 10) and experimental (n = 8) groups. Athletes were assessed before and after the training program for stature, body mass, core stability, electromyographic activity of the abdominal and back muscles, treadmill VO2max, running economy, and running posture. The experimental group performed 2 Swiss ball training sessions per week for 6 weeks. Data analysis revealed a significant effect of Swiss ball training on core stability in the experimental group ($p < 0.05$). No significant differences were observed for myoelectric activity of the abdominal and back muscles, treadmill VO2max, running economy, or running posture in either group. It appears Swiss ball training may positively affect core stability without concomitant improvements in physical performance in young athletes. Specificity of exercise selection should be considered.

Publication Types:

- Clinical Trial
- Controlled Clinical Trial

PMID: 15320664 [PubMed - indexed for MEDLINE]

J Strength Cond Res. 2003 Aug;17(3):475-83.

Electromyographic comparison of the upper and lower rectus abdominis during abdominal exercises.

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The objective of this pilot study was to determine the effect of 6 different abdominal exercises on the electrical activity of the upper rectus abdominis (URA) and lower rectus abdominis (LRA). Eight healthy, adult volunteers completed 6 random abdominal exercises: curl up, Sissel ball curl up, Ab Trainer curl up, leg lowering, Sissel ball roll out, and reverse curl up. Action potentials were recorded and analyzed from the URA and the LRA using surface electromyography (EMG) during a 2-second concentric contraction. The average normalized data were compared between the URA and the LRA in order to determine the behavior of the different muscle sites and between exercises in order to determine which exercises elicited the highest EMG activity. There were no significant differences ($p > 0.05$) between the EMG activity of the URA and LRA during any exercise. There were no significant interactions between subject and muscle site or between exercise and muscle site. Significant differences were found among the 6 exercises performed, and due to the interaction between subject and exercise performed. Both the URA and the LRA recorded significantly higher mean amplitudes during the Sissel ball curl up than during all other exercises. In addition, the curl up, Sissel ball curl up, and Ab Trainer curl up had significantly higher normalized EMG activity in both muscle sites than the reverse curl up, the leg lowering exercise, and the Sissel ball roll out. The curl up and the Ab Trainer curl up exercises were not significantly different in terms of their normalized EMG activities for both the URA and the LRA.

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J Strength Cond Res. 2002 Aug;16(3):416-22.

Muscle force and activation under stable and unstable conditions.

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The objective of this study was to determine differences in isometric force output, muscle activation (interpolated twitch technique), and electromyographic activity of the quadriceps, plantar flexors (PF), and their antagonists under stable and unstable conditions. Instability in subjects was introduced by making them perform contractions while seated on a "Swiss ball." Eight male subjects performed unilateral leg extensor (LE) and PF contractions while seated on a bench (LE), chair (PF), or a ball. Unstable LE and PF forces were 70.5 and 20.2% less than their stable counterparts, respectively. Unstable quadriceps and PF activation averaged 44.3 and 2.9% less than activation under stable conditions. Unstable antagonist/agonist ratios were 40.2 and 30.7% greater than stable ratios in the LE and PF protocols, respectively. The greater decrements with LE can be attributed to the instability of only 2 points of floor contact, rather than 3 points of floor contact as with the PF. Swiss balls may permit a strength training adaptation of the limbs, if instability is moderate, allowing the production of overload forces.

PMID: 12173956 [PubMed - indexed for MEDLINE]

Phys Ther. 2000 Jun;80(6):564-9.

Physical Therapy
Full Text Online

Abdominal muscle response during curl-ups on both stable and labile surfaces.

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BACKGROUND AND PURPOSE: With the current interest in stability training for the injured low back, the use of labile (movable) surfaces, underneath the subject, to challenge the motor control system is becoming more popular. Little is known about the modulating effects of these surfaces on muscle activity. The purpose of this study was to establish the degree of modulating influence of the type of surface (whether stable or labile) on the mechanics of the abdominal wall. In this study, the amplitude of muscle activity together with the way that the muscles coactivated due to the type of surface under the subject were of interest. SUBJECTS: Eight men (mean age=23.3 years [SD=4.3], mean height=177.6 cm [SD=3.4], mean weight=72.6 kg [SD=8.7]) volunteered to participate in the study. All subjects were in good health and reported no incidence of acute or chronic low back injury or prolonged back pain prior to this experiment. METHODS: All subjects were requested to perform 4 different curl-up exercises-1 on a stable surface and the other 3 on varying labile surfaces. Electromyographic signals were recorded from 4 different abdominal sites on the right and left sides of the body and normalized to maximal voluntary contraction (MVC) amplitudes. RESULTS: Performing curl-up exercises on labile surfaces increased abdominal muscle activity (eg, for curl-up on a stable surface, rectus abdominis muscle activity was 21% of MVC and external oblique muscle activity was 5% of MVC; for curl-up with the upper torso on a labile ball, rectus abdominis muscle activity was 35% of MVC and external oblique muscle activity was 10% of MVC). Furthermore, it appears that increases in external oblique muscle activity were larger than those of other abdominal muscles. CONCLUSION AND DISCUSSION: Performing curl-ups on labile surfaces changes both the level of muscle activity and the way that the muscles coactivate to stabilize the spine and the whole body. This finding suggests a much higher demand on the motor control system, which may be desirable for specific stages in a rehabilitation program.

PMID: 10842409 [PubMed - indexed for MEDLINE]

Am J Sports Med. 1996 May-Jun;24(3):386-92.

An electromyographic analysis of the shoulder during a medicine ball rehabilitation program.

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We used dynamic electromyography and a motion analysis system to describe the muscle firing patterns in 10 shoulder muscles and the basic kinematics of a two-handed overhead medicine ball throw. Ten healthy male subjects with no history of shoulder injury were evaluated. The two-handed medicine ball throw was divided into three phases for analysis: cocking, acceleration, and deceleration. The average duration of the throw was 1.92 seconds; the cocking phase represented 56%, the acceleration phase 15.5%, and the deceleration phase 28.5% of the throw. In the cocking phase, the upper trapezius, pectoralis major, and anterior deltoid muscles showed high activity (> 40% to 60% maximum manual test), and the rotator cuff muscles had moderate activity (> 20% to 40%). In the acceleration phase, five of the muscles demonstrated high levels of activity (> 40% to 60%) and the upper trapezius and lower subscapularis muscles had very high levels of activity (> 60%). Analysis of the deceleration phase revealed high activity in the upper trapezius muscle and moderate activity in all other muscles except the pectoralis major. Our findings support the use of medicine ball training as a bridge between static resistive training and dynamic throwing in the rehabilitation of the overhead athlete. This training technique provides a protective method of strengthening that closely simulates portions of the throwing motion.

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J Neurophysiol. 1995 Feb;73(2):820-35.

Control of limb dynamics in normal subjects and patients without proprioception.

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1. We recently showed that patients lacking proprioceptive input from their limbs have particular difficulty performing multijoint movements. In a pantomimed slicing gesture requiring sharp reversals in hand path direction, patients showed large hand path distortions at movement reversals because of failure to coordinate the timing of the separate reversals at the shoulder and elbow joints. We hypothesized that these reversal errors resulted from uncompensated effects of inertial interactions produced by changes in shoulder joint acceleration that were transferred to the elbow. We now test this hypothesis and examine the role of proprioceptive input by comparing the motor performance of five normal subjects with that of two patients with large-fiber sensory neuropathy. 2. Subjects were to trace each of six template lines presented randomly on a computer screen by straight overlapping out-and-back movements of the hand on a digitizing tablet. The lines originated from a common starting position but were in different directions and had different lengths. Directions and lengths were adjusted so that tracing movements would all require the same elbow excursion, whereas shoulder excursion would vary. The effects of varying interaction torques on elbow kinematics were then studied. The subject's dominant arm was supported in the horizontal plane by a low-inertia brace equipped with ball bearing joints and potentiometers under the elbow and shoulder. Hand position was monitored by a magnetic pen attached to the brace 1 cm above a digitizing tablet and could be displayed as a screen cursor. Vision of the subject's arm was blocked and the screen cursor was blanked at movement onset to prevent visual feedback during movement. Elbow joint torques were calculated from joint angle recordings and compared with electromyographic recordings of elbow joint musculature. 3. In control subjects, outward and inward paths were straight and overlapped the template lines regardless of their direction. As prescribed by the task, elbow kinematics remained the same across movement directions, whereas interaction torques varied substantially. The timing of the onsets of biceps activity and the offsets of triceps activity during elbow flexion varied systematically with direction-dependent changes in interaction torques. Controls exploited or dampened these interaction torques as needed to meet the kinematic demands of the task. 4. In contrast, the patients made characteristic errors at movement reversals that increased systematically across movement directions. These reversal errors resulted from improper timing of elbow and shoulder joint reversals.(ABSTRACT TRUNCATED AT 400 WORDS)

PMID: 7760137 [PubMed - indexed for MEDLINE]

Int J Sports Med. 1997 Nov;18(8):618-24.

Recruitment patterns of the scapular rotator muscles in freestyle swimmers with subacromial impingement.

Wadsworth DJ, **Bullock-Saxton JE**.

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Athletes with shoulder pathology consistently demonstrate abnormalities in scapular rotator activity, suggesting that muscle dysfunction is a factor to consider in the aetiology or recurrence of shoulder pain. However, one important measure of the coordinated activity between the scapular rotators, their timing or temporal recruitment pattern, remains undetermined. The purposes of this study were to 1. provide normative data on the temporal recruitment pattern of the scapular rotators in freestyle swimmers, 2. determine the effect of a unilateral shoulder injury on this pattern, 3. determine whether these effects extend to the non-injured side, and 4. determine the effect of injury on the consistency (variability) of muscle recruitment. Surface EMG data for the upper and lower trapezius and serratus anterior were recorded bilaterally from two groups of competitive freestyle swimmers during controlled bilateral elevation in the plane of the scapula. An injured group comprising nine swimmers with unilateral shoulder pathology and a control group of nine non-injured swimmers were included. Temporal data determined for the onset of muscle activation for each muscle were then compared between groups using an ANOVA and a one-sided F test. The results of the study indicate that in non-injured swimmers, upper trapezius is activated 217 ms prior to shoulder motion, followed by serratus anterior activation 53 ms after motion commences. Lower trapezius was not recruited until 349 ms after shoulder motion, when the arm had attained 15 degrees elevation. In injured swimmers, all three muscles on the injured side displayed significantly increased variability in the timing of activation ($p < 0.05$), whilst the serratus anterior was significantly delayed in its activation on the non-injured side ($p < 0.05$). Skill hand preference was shown to have no effect on muscle recruitment. The findings of this study indicate that a relationship does exist between shoulder injury and the temporal recruitment patterns of the scapular rotators, such that injury reduces the consistency of muscle recruitment. They further suggest that injured subjects have muscle function deficits on their unaffected side.

PMID: 9443596 [PubMed - indexed for MEDLINE]

J Sports Med Phys Fitness. 1996 Jun;36(2):121-6.

The frontcrawl downsweep: shoulder protection and/or performance inhibition.

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EMG of 6 shoulder and arm muscles was measured in nine good frontcrawl swimmers using active electrodes and a telemetric EMG data acquisition system. The raw EMG was low pass filtered, rectified and the integrated values were used as a measure of muscular intensity. The selection of muscles combined 2 mono-articular and 2 bi-articular shoulder muscles and 2 muscular primarily acting on elbow & wrist. Kinematic analysis allowed for a detailed time and movement pattern fractionation and the muscle activity within these phases was analysed for 4 x 100 m at maximum effort up to exhaustion. The combination of time distribution and muscular activity suggested that the downsweep is the longest in time but with the lowest intensity of all 4 transient phases of the cyclic arm movement. This is assumed to be effective for decreasing the load of the shoulder joint. However, it could also be considered that if the insweep with its higher muscular participation could start earlier in the pull phase while shortening the downsweep. The higher, but more constant loading of the shoulder might improve performance.

PMID: 8898519 [PubMed - indexed for MEDLINE

Arch Physiol Biochem. 1997 Dec;105(7):655-62.

Muscular activations during repetitions of sculling movements up to exhaustion in swimming.

Rouard AH, **Billat RP**, **Deschodt V**, **Clarys JP**.

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The purpose of this study was to examine the influence of the repetition of sculling movements of the upper limb on muscular electrical activities during an exhaustive test in front crawl. Six upper limb muscles activities of nine swimmers were recorded, with telemetric EMG data acquisition system using active surface electrodes, during a 4 x 100 m front crawl test conducted to exhaustion. The pattern of the movement was analysed from views obtained by recordings of two underwater cameras. Four phases in the stroke were identified from the hand coordinates in the frontal plane (down-sweep, insweep, outsweep and recovery). Raw EMG were rectified, integrated (IEMG) and normalized for each subject and for each muscle with respect to the highest IEMG obtained during the strokes and the phases. Results indicated that the repetition of the stroke up to exhaustion was not associated with an increase in IEMG for the total stroke and its phases excepted for the most activated muscle. The different sculling movements appeared to be clearly identify by the EMG approach whatever the trial. The contribution of the different muscles remained the same through the different repetitions up to exhaustion. The larger muscular recruitments were obtained during the insweep phase when important antagonist activities were observed. It would be interesting to observe the EMG in a next 100 m repetition when the swimmer could not sustain the same velocity.

PMID: 9693712 [PubMed - indexed for MEDLINE]

Clin Biomech (Bristol, Avon). 2000 Feb;15(2):95-102.

ELSEVIER FULL-TEXT ARTICLE

EMG and strength correlates of selected shoulder muscles during rotations of the glenohumeral joint.

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OBJECTIVE: To identify activation patterns of several muscles acting on the shoulder joint during isokinetic internal and external rotation. DESIGN: Combined EMG and isokinetic strength analysis in healthy subjects. BACKGROUND: EMG studies of the shoulder region revealed intricate muscular activation patterns during elevation of the arm but no parallel studies regarding pure rotations of the joint could be located. METHODS: Fifteen (n=30 shoulders) young, asymptomatic male subjects participated in the study. Strength production during isokinetic concentric and eccentric internal and external rotations at 60 and 180 degrees /s was correlated with the EMG activity of the rotator cuff, biceps, deltoid and pectoralis major. Analysis of the smoothed EMG related to the timing of onset of the signal and to the normalized activity at the angle of the peak moment. Determination of the association between the EMG and the moment was based on strength ratios. RESULTS: Findings indicated that for both types of rotations, the rotator cuff and biceps were active 0.092+/-0.038-0.215+/-0.045 s prior to the initiation of the actual movement and 0.112-0.034 s prior to onset of deltoid and pectoralis major activity. These differences were significant in all of the eight conditions (P<0.05). In terms of the strength ratios, strong association was found between electrical activity and moment production in the subscapularis and infraspinatus (r(2)=0.95 and 0. 72, respectively) at the low and high angular velocities. CONCLUSIONS: Prior to actual rotation of the shoulder joint, normal recruitment of the rotator cuff and biceps is characterized by a non-specific presetting phase which is mainly directed at enhancing the joint 'stiffness' and hence its stability. Once movement is in progress, the EMG patterns of these muscles become movement specific and are correlated with the resultant moment. RELEVANCE: Muscular dysfunction relating to delayed onset activity or altered activation patterns, due to pain, perturbed mechanics or disturbed neural activation have been implicated as concomitant factors in other joint associated pathologies. Through highlighting the role of the rotator cuff in shoulder joint rotations, this study lends further support to the argument that a parallel situation may prevail with respect to shoulder joint dysfunction. This could lead to the development of rehabilitation protocols aimed specifically at redressing such dysfunction.

Publication Types:

- Clinical Trial

PMID: 10627325 [PubMed - indexed for MEDLINE]

Exp Brain Res. 1997 Jun;115(2):191-205.

SpringerLink FULL-TEXT ARTICLE

Arm-movement-related neurons in the primate superior colliculus and underlying reticular formation: comparison of neuronal activity with EMGs of muscles of the shoulder, arm and trunk during reaching.

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Neuronal activity was recorded from the superior colliculus (SC) and the underlying reticular formation in two monkeys during an arm reaching task. Of 744 neurons recorded, 389 (52%) clearly modulated their activity with arm movements. The temporal activity patterns of arm-movement-related neurons often had a time course similar to rectified electromyograms (EMGs) of particular muscles recorded from the shoulder, arm or trunk. These reach cells, as well as the muscles investigated, commonly exhibited mono- or biphasic (less frequently tri- or polyphasic) excitatory bursts of activity, which were related to the (pre-)movement period, the contact phase and/or the return movement. The vast majority of reach cells exhibited a consistent activity pattern from trial to trial as did most of the muscles of the shoulder, arm and trunk. Similarities between the activity patterns of the neurons and the muscles were sometimes very strong and were especially notable with the muscles of the shoulder girdle (e.g. trapezius descendens, supraspinatus, infraspinatus or the anterior and medial deltoids). This high degree of co-activation suggests a functional linkage, though not direct, between the collicular reach cells and these muscles. Neuronal activity onset was compared with that of 25 muscles of the arms, shoulders and trunk. The majority of cells (78.5%) started before movement onset with a mean lead time of 149+/-90 ms, and 36.5% were active even before the earliest EMG onset. The neurons exhibited the same high degree of correlation (r=0.97, Spearman rank) between activity onset and the beginning of the arm movement as did the muscles (r=0.98) involved in the task. The mean neuronal reach activity (background subtracted) ranged between 7 and 193 impulses/s (mean 40.5+/-24.2). The mean modulation index calculated [(reach activity background activity)/reach activity+background activity)] was 0.75+/-0.23 for neurons (n=358) and 0.87+/-0.14 for muscles (n=25). As the monkeys fixated the reach target constantly during an arm movement, neuronal activity which was modulated in this period was not related to eye movements. The three neck muscles investigated in the reach task exhibited no reach-related activity modulation comparable to that of either the reach cells or the muscles of the shoulder, arm and trunk. However, tonic neck muscle EMG was monotonically related to horizontal eye position. The clear skeletomotor discharge characteristics of arm-movement-related SC neurons revealed in this study agree with those already known from other sensorimotor regions (for example the primary motor, the premotor and parietal cortex, the basal ganglia or the cerebellum) and are consistent with the possible role of this population of reach cells in the control of arm movements.

PMID: 9224849 [PubMed - indexed for MEDLINE]

Clin Sports Med. 1983 Jul;2(2):247-70.

Anatomy and biomechanics of the shoulder in throwing, swimming, gymnastics, and tennis.

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As the most mobile joint in the body, the shoulder is structurally insecure. The ball-shaped humeral head rotates and glides on a shallow scapular cup. A limited amount of passive stability is provided by the glenoid labrum, which slightly deepens the scapular cup, and by ligaments reinforcing the capsule on its superior and anterior surfaces. At peak maturity ligamentous restraint equals 50 to 80 kg. These structural limitations indicate that the primary source of joint stability must be balanced muscle control. Joint compression is the major factor. This is supplemented by active tangential restraint, which selectively opposes anterior, posterior, or superior displacement. The large external muscles used for purposeful motion and speed often create subluxating shear forces in addition to the desired actions. Impingement and attrition syndromes are common consequences. To counter this, as well as to provide selective rotation, there are the four muscles that constitute the rotator cuff. Joint compression is the major force generated by the supraspinatus and infraspinatus. The latter (accompanied by the teres minor) also provides a downward pull to oppose the upward displacement of early deltoid action. Anterior protection against excessive external rotation or extension is offered by the subscapularis. Athletic who use the arm for a propelling force strain the extremes of joint range in their drive for maximum performance. The threat of injury can be minimized by two actions, namely, modifying motion patterns, which may avoid impingement or make it a less frequent experience, and active protection, which is gained through specific strengthening of the rotator cuff muscles.

Publication Types:

- Review
- Review, Tutorial

PMID: 9697636 [PubMed - indexed for MEDLINE]

Am J Sports Med. 1986 Jan-Feb;14(1):7-11.

Fine wire electromyography analysis of muscles of the shoulder during swimming.

Nuber GW, Jobe FW, Perry J, Moynes DR, Antonelli D.

Fine wire EMG of the shoulder was performed on 11 swimmers; 5 performed during dry land studies and 7 during aquatic studies. One individual underwent both studies. A cinematographic analysis was synchronized with the EMG data to determine what muscles were firing at each phase of the swim stroke. Eight muscles were studied: biceps, subscapularis, latissimus dorsi, pectoralis major, supraspinatus, infraspinatus, serratus anterior, and deltoid. Three strokes were analyzed: freestyle, breaststroke, and butterfly. The freestyle and butterfly are frequently associated with impingement type syndromes in swimmers. It was determined that the supraspinatus, infraspinatus, middle deltoid, and serratus anterior were predominately recovery phase muscles. The latissimus dorsi and pectoralis major were predominately pull-through phase muscles. The biceps had mixed inconsistent activity during both phases. From dry land quantifications of the EMG signal it was determined that the serratus anterior functions near maximal muscle test during each stroke, and theoretically may fatigue with repetition. It is hoped that a training program aimed to strengthen the scapular rotators may help alleviate impingement syndrome in swimmers.

PMID: 3752349 [PubMed - indexed for MEDLINE]

Clin Orthop Relat Res. 1993 Mar;(288):27-34.

Electromyographic analysis and its role in the athletic shoulder.

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In 1944, Inman made some conclusions regarding shoulder function that have become the foundation of a classic model. Clinical observations of the athletic shoulder and its associated common injuries have demonstrated selective weakness of specific rotator cuff muscles rather than generalized muscle impairment. Shoulder mechanics during athletic activities have been evaluated dynamically with electromyography (EMG), which has helped to formulate a base for optimal rehabilitation. Dynamic EMG and high-speed film analysis have been used to evaluate the shoulder during throwing, swimming, tennis, and golf. Evaluation of shoulder function in these various sports revealed that although rotator cuff function is important in all, the emphasis and role of individual muscles varied. The importance of serratus anterior muscle activity to stabilization and protraction of the scapula has been consistently reported. The muscles about the shoulder act according to their mechanical qualities and are function- or sport-specific. A thorough understanding of the mechanics of the normal and pathologic shoulder constitutes the foundation for training and rehabilitation strategies.

PMID: 8458143 [PubMed - indexed for MEDLINE]

Clin Orthop Relat Res. 1993 Mar;(288):179-88.

A kinematic and electromyographic study of shoulder rehabilitation exercises.

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The role of shoulder muscles during passive, active, and resistive phases of shoulder rehabilitation exercises was investigated in ten normal subjects with no history of shoulder pathology. Using the scapular plane as a reference, three-dimensional motion of the shoulder was recorded with a computer-aided motion analysis system (VICON) to determine total shoulder elevation. Simultaneously, electromyographic data were acquired on nine shoulder muscles while performing the three phases of shoulder rehabilitation exercises as described by Neer. Fine wire intramuscular electrodes were placed in the following muscles: trapezius, serratus anterior, deltoid (anterior, middle, and posterior separately), supraspinatus, infraspinatus, biceps, and latissimus dorsi. Phase I (passive) exercises performed in the supine position showed the least electromyography (EMG) activity. There was a gradation of EMG activity as one progressed from Phase I (passive) to Phase II (active) to Phase III (resistive) shoulder exercises. Isometric exercises and Phase III resistive exercises showed high levels of activity in the rotator cuff and deltoid muscles. Supine Phase I exercises should be considered in the early postoperative period after shoulder surgery to achieve maximum motion while minimizing shoulder muscle activity. Progression to Phase II and Phase III exercises may proceed as soft tissue and bony healing permit. Phase III exercises performed with an elastic band should provide a satisfactory method to strengthen these muscles.

PMID: 8458132 [PubMed - indexed for MEDLINE

Clin Orthop Relat Res. 1991 Aug;(269):181-92.

Differences in shoulder muscle activity between patients with generalized joint laxity and normal controls.

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The aim of the present study was to analyze shoulder muscle activity in patients with generalized joint laxity and shoulder instability and to compare it with muscle activity recorded in healthy subjects from an earlier study. Electromyographic (EMG) activity was recorded from eight shoulder muscles in six patients using surface and intramuscular fine-wire electrodes. Recordings were made from the subscapularis, supraspinatus, infraspinatus, pectoralis major (sternoclavicular part), the anterior, middle, and posterior parts of the deltoid, and the latissimus dorsi. The EMG signal was low-pass filtered, full-wave rectified, and time-average. Normalization of the EMG allowed interindividual and intraindividual comparisons. During abduction and flexion, muscle activity in the anterior and middle parts of the deltoid was significantly decreased in the patients, and during internal rotation activity in the subscapularis was increased. As in healthy subjects, patients showed simultaneous activity in both those muscles producing the movement and in the antagonistic muscles. The altered muscle activity observed in patients with generalized joint laxity provides (1) a basis for understanding the mechanism of their shoulder instability and (2) the rationale for a physical training program for these patients.

PMID: 1864037 [PubMed - indexed for MEDLINE]

J Shoulder Elbow Surg. 1996 Mar-Apr;5(2 Pt 1):118-23.

Comparative electromyographic analysis of shoulder muscles during planar motions: anterior glenohumeral instability versus normal.

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This study compared the electromyographic activity of rotator cuff and scapular muscles between subjects with anterior instability and subjects with normal shoulders. Thirty-eight patients were studied; 23 had anterior instability that was subsequently surgically confirmed, and 15 had normal shoulders. Fine wire electrodes were inserted into the subscapularis (upper and lower portions), supraspinatus, infraspinatus, rhomboid, serratus anterior, and trapezius (upper and lower portions) muscles. Abduction, scapular plane abduction (scaption), and forward flexion were performed over the range of motion and later divided into 30 degrees intervals. In both abduction and scaption, the supraspinatus demonstrated significantly less electromyographic activity from 30 degrees to 60 degrees in shoulders with anterior instability compared with normal shoulders ($p < 0.05$). During all three motions, shoulders with anterior instability demonstrated significantly less electromyographic activity in the serratus anterior when compared with normal shoulders ($p < 0.05$). This occurred at 30 degrees to 120 degrees of abduction and at 0 degree to 120 degrees of scaption and forward flexion. None of the other muscles demonstrated significant differences. These differences during planar motions were similar to those demonstrated during challenging overhead sport motions. Early rehabilitation efforts should focus both on the rotator cuff and scapular muscles to establish smooth, coordinated shoulder motion.

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Muscle activity and coordination in the normal shoulder. An electromyographic study.

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Muscle activity and coordination in ten shoulders were studied in five healthy subjects using electromyography (EMG) recorded during standardized loaded movements, i.e., flexion, extension, abduction, external rotation, and internal rotation at 0 degrees, 45 degrees, and 90 degrees of abduction. Bipolar surface and intramuscular fine-wire electrodes were used, and the EMG signal was low-pass filtered, full-wave rectified, and time-averaged. Activity from the subscapularis, supraspinatus, infraspinatus, pectoralis major (sternoclavicular part), the anterior, middle, and posterior parts of the deltoid, and the latissimus dorsi was recorded in parallel. In order to allow a comparison of the activity in a subject's different muscles and the activity in specific muscles between different individuals, the EMG was normalized. Muscle activity occurred simultaneously in muscles producing the movement and in antagonistic muscles. Coordination due to muscle contractions plays a significant role in stabilizing the shoulder joint. The infraspinatus, subscapularis, and latissimus dorsi acted as stabilizers during flexion; the subscapularis acted as a stabilizer during external rotation and with the supraspinatus during extension.

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Phys Ther. 1993 Oct;73(10):668-77; discussion 677-82.

Electromyographic activity of selected shoulder muscles in commonly used therapeutic exercises.

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BACKGROUND AND PURPOSE. The purpose of this study was to evaluate and compare the muscle activity of the supraspinatus, infraspinatus, teres minor, and lower trapezius muscles during commonly prescribed therapeutic exercises in subjects with and without shoulder pathology. SUBJECTS. Twenty healthy subjects (9 male, 11 female) and 20 subjects with recurrent unilateral shoulder pain and weakness (14 male, 6 female), aged 18 to 40 years (mean = 28, SD = 5.8), participated in this study. METHODS. Subjects performed each of the following exercises using a hand-held weight: prone lateral (external) rotation, sidelying lateral rotation, and arm elevation in the scapular plane. Indwelling fine-wire electrodes recorded electromyographic (EMG) activity during each exercise. The EMG activity in five phases of concentric contraction of each exercise was averaged and divided into three equal time intervals. Mean EMG values normalized to maximal activity for the entire phase of concentric contraction and for each of the three intervals were used in subsequent analyses. RESULTS. Two-way repeated-measures analyses of variance (ANOVAs) revealed between-group differences only in the prone lateral rotation exercise. Compared with subjects without shoulder pathology, subjects with shoulder pain showed significantly greater EMG activity in the infraspinatus muscle and less activity in the supraspinatus muscle during this exercise. CONCLUSION AND DISCUSSION. These results suggest that the pattern of muscle activation during specific shoulder movements in patients with shoulder pain may be related to pathology. Future studies are needed to determine whether an imbalance in neuromuscular control is a factor contributing directly to shoulder dysfunction or whether such an imbalance is secondary to some pathology.

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Am J Sports Med. 1992 Mar-Apr;20(2):128-34.

EMG analysis of the scapular muscles during a shoulder rehabilitation program.

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The purpose of this study was to determine which exercises most effectively use the scapular muscles. Eight muscles in 9 healthy subjects were studied with indwelling electromyographic electrodes and cinematography while performing 16 exercises. The 8 muscles studied were the upper, middle, and lower trapezius; levator scapula; rhomboids; pectoralis minor; and the middle and lower serratus anterior. Each exercise was divided into arcs of motion and the electromyographic activity was quantified as a percentage of the maximal manual muscle test. The optimal exercises for each muscle were identified based on intensity (greater than 50% maximal manual muscle test) and duration (over at least 3 consecutive arcs of motion) of the muscle activity. Twelve of the exercises qualified as top exercises for all of the muscles. On further analysis, a group of 4 exercises was shown to make up the core of a scapular muscle strengthening program. Those 4 exercises include scaption (scapular plane elevation), rowing, push-up with a plus, and press-up.

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Surface electromyographic analysis of exercises for the trapezius and serratus anterior muscles.

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STUDY DESIGN: This study used a prospective, single-group repeated-measures design to analyze differences between the electromyographic (EMG) amplitudes produced by exercises for the trapezius and serratus anterior muscles. OBJECTIVE: To identify high-intensity exercises that elicit the greatest level of EMG activity in the trapezius and serratus anterior muscles. BACKGROUND: The trapezius and serratus anterior muscles are considered to be the only upward rotators of the scapula and are important for normal shoulder function. Electromyographic studies have been performed for these muscles during active and low-intensity exercises, but they have not been analyzed during high intensity exercises. METHODS AND MEASURES: Surface electrodes recorded EMG activity of the upper, middle, and lower trapezius and serratus anterior muscles during 10 exercises in 30 healthy subjects. RESULTS: The unilateral shoulder shrug exercise was found to produce the greatest EMG activity in the upper trapezius. For the middle trapezius, the greatest EMG amplitudes were generated with 2 exercises: shoulder horizontal extension with external rotation and the overhead arm raise in line with the lower trapezius muscle in the prone position. The arm raise overhead exercise in the prone position produced the maximum EMG activity in the lower trapezius. The serratus anterior was activated maximally with exercises requiring a great amount of upward rotation of the scapula. The exercises were shoulder abduction in the plane of the scapula above 120 degrees and a diagonal exercise with a combination of shoulder flexion, horizontal flexion, and external rotation. CONCLUSION: This study identified exercises that maximally activate the trapezius and serratus anterior muscles. This information may be helpful for clinicians in developing exercise programs for these muscles.

Publication Types:

- Clinical Trial

PMID: 12774999 [PubMed - indexed for MEDLINE]

Clin Orthop Relat Res. 1995 May;(314):143-51.

Electromyographic recordings in shoulder muscles during eccentric movements.

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The purpose of the present study was to investigate shoulder muscle activity during eccentric muscle movements, and to determine whether electromyograms in patients with joint laxity differed from those in normal subjects. Five normal subjects and 6 patients with generalized joint laxity and shoulder instability were studied. Both shoulders were investigated. Normalized electromyograms were recorded during eccentric loaded movements from 8 shoulder muscles in parallel. Intra-muscular fine wire electrodes were used for 3 muscles of the rotator cuff: subscapularis, supraspinatus, and infraspinatus. Surface electrodes were used for superficially located muscles: the anterior, middle, and posterior parts of the deltoid, pectoralis major, and latissimus dorsi. A general trend was an activation of several muscles rather than a single muscle during all movements investigated. Patients with generalized joint laxity activated their supraspinatus and subscapularis muscles to a higher level during flexion and adduction movements than normal subjects did. This might indicate a greater necessity for muscular activity to provide anterior shoulder stability in lax joints. Compared with concentric movements previously studied, results from this study showed that the magnitude of activation was significantly lower during eccentric movements in normal subjects and in patients with joint laxity.

PMID: 7634627 [PubMed - indexed for MEDLINE]

Am J Sports Med. 1998 Mar-Apr;26(2):210-20.

Electromyographic activity and applied load during shoulder rehabilitation exercises using elastic resistance.

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Muscle activity (measured by electromyography) and applied load were measured during seven shoulder rehabilitation exercises done with an elastic resistance device. Nineteen men with no shoulder abnormalities performed seven exercises: external and internal rotation, forward punch, shoulder shrug, and seated rowing with a narrow, middle, and wide grip. Qualitative video (60 Hz) was synchronized with the electromyography data from eight muscles (2000 Hz). Fine-wire intramuscular electrodes were inserted into the supraspinatus and subscapularis muscles, and surface electrodes were placed over the anterior deltoid, infraspinatus, pectoralis major, latissimus dorsi, serratus anterior, and trapezius muscles. Ten trials per subject were analyzed for average and peak amplitude, and the results were expressed as a percentage of maximum voluntary contractions. The peak loads for all exercises ranged from 21 to 54 N. The muscle activity patterns suggest that these shoulder rehabilitation exercises incorporating elastic resistance, controlled movements, and low initial loading effectively target the rotator cuff and supporting musculature and are appropriate for postinjury and postoperative patients.

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Clin Sports Med. 1983 Jul;2(2):247-70.

Anatomy and biomechanics of the shoulder in throwing, swimming, gymnastics, and tennis.

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As the most mobile joint in the body, the shoulder is structurally insecure. The ball-shaped humeral head rotates and glides on a shallow scapular cup. A limited amount of passive stability is provided by the glenoid labrum, which slightly deepens the scapular cup, and by ligaments reinforcing the capsule on its superior and anterior surfaces. At peak maturity ligamentous restraint equals 50 to 80 kg. These structural limitations indicate that the primary source of joint stability must be balanced muscle control. Joint compression is the major factor. This is supplemented by active tangential restraint, which selectively opposes anterior, posterior, or superior displacement. The large external muscles used for purposeful motion and speed often create subluxating shear forces in addition to the desired actions. Impingement and attrition syndromes are common consequences. To counter this, as well as to provide selective rotation, there are the four muscles that constitute the rotator cuff. Joint compression is the major force generated by the supraspinatus and infraspinatus. The latter (accompanied by the teres minor) also provides a downward pull to oppose the upward displacement of early deltoid action. Anterior protection against excessive external rotation or extension is offered by the subscapularis. Athletic who use the arm for a propelling force strain the extremes of joint range in their drive for maximum performance. The threat of injury can be minimized by two actions, namely, modifying motion patterns, which may avoid impingement or make it a less frequent experience, and active protection, which is gained through specific strengthening of the rotator cuff muscles.

Publication Types:

- Review
- Review, Tutorial

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Arch Phys Med Rehabil. 2001 Aug;82(8):1089-98.

ELSEVIER FULL-TEXT ARTICLE

Back and abdominal muscle function during stabilization exercises.

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OBJECTIVES: To assess the paraspinal and abdominal muscle activities during different therapeutic exercises and to study how load increment produced by varying limb movements and trunk positions could affect these muscle activities. DESIGN: A cross-sectional study comparing muscle activities between men and women. SETTING: Rehabilitation clinic in university hospital. PARTICIPANTS: Twenty-four healthy volunteers (14 women, 10 men) aged 21 to 39 years. INTERVENTIONS: Subjects performed 16 different therapeutic exercises commonly used to treat low back pain. MAIN OUTCOME MEASURES: Surface electromyography was recorded from the paraspinal (T9, L5) and abdominal (rectus abdominis, obliquus externus) muscles during these exercises. Average electromyographic amplitudes obtained during the exercises were normalized to the amplitude in maximal voluntary contraction (% MVC) to produce interindividually comparable muscle activity assessments. RESULTS: Mean average normalized electromyographic amplitudes (% MVC) of the exercises were below 50% MVC. At L5 level, the multifidus muscle activities were significantly higher ($p < .05$) in women than in men, whereas no significant difference was found at T9 level. Similarly, rectus abdominis and obliquus externus activities were significantly higher ($p < .001$, $p < .05$) in women than in men. Load increment in hands or unbalanced trunk and limb movements produced higher paraspinal and abdominal muscle activities ($p < .05$). CONCLUSIONS: Simple therapeutic exercises are effective in activating both abdominal and paraspinal muscles. By changing limb and trunk positions or unbalancing trunk movements, it is possible to increase trunk muscle activities. Women were better able to activate their stabilizing trunk muscles than men; but it is also possible that men, having a much higher degree of strength on maximal contraction, only need to activate a smaller amount of that maximum to perform a similar activity.

Publication Types:

- Clinical Trial

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