Medicina Sportiva
Med Sport 17 (2): 67-71, 2013
DOI: 10.5604/17342260.1055261
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ELECTROMYOGRAPHICAL ANALYSIS OF THE DELTOID BETWEEN DIFFERENT STRENGTH TRAINING EXERCISES

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Abstract

Introduction: The neural requirement is variable between different strength exercises and the appropriate choice of exercises will influence the strength training adaptations. However, the selection of exercises that are suitable to compose a strength training program according to the level of muscular activation still has little scientific support.

Objective: To compare different upper limb strength training exercises according to the electromyographic (EMG) activity of three different portions of the deltoid muscle.

Methods: Eight strength trained males participated in the study. EMG signals of the anterior, medial and posterior deltoid were collected at maximal isometric voluntary contraction (MVIC) and for the following exercises at a 10 repetition maximum load: bench press, smith machine shoulder press, peck deck, reverse peck deck, free weight lateral raise, cable crossover lateral raise, incline lat pull-down and seated row.

Results: The anterior deltoid was similarly activated ($P > 0.05$) during the smith machine shoulder press (≈70%), bench press (≈55%) and peck deck (≈50%), and significantly more activated in the smitch machine shoulder press than during the other exercises ($P < 0.05$). The medial deltoid showed similar activation ($P > 0.05$) during lateral raises (≈55%), reverse peck deck (≈48%) and seated row (≈40%), while the posterior deltoid exhibited similar activation($P > 0.05$) during reverse peck deck (≈90%), incline lat pull-down (≈58%) and seated row (≈54%), and was significantly more activated in the reverse peck deck than during other exercises ($P < 0.05$).

Conclusions: According to these results, it is possible to determine which upper limb exercises are indicated for the development of the three portions of the deltoid muscle via muscle activation.

Key words: *surface electromyography, strength training, strength exercises, deltoid muscle, shoulder*

Introduction

Strength training has been widely used for performance and health reasons. To plan a proper training program it is necessary to incorporate and appropriately manipulate the acute strength training variables [1-3]. Acute variables such as intensity, volume, choice of exercises, order of exercises, rest periods, frequency and repetition velocity are the main variables that affect the results of training [2,4]. When adequately manipulated, these variables result in specific physiological adaptations that allow the predetermined goals to be attained as well as control and progression of the training cycles.

Due to variable neural requirement between different exercises [5] the appropriate choice of exercises will influence strength training adaptations. Thus, the choice of exercises should be in accordance with the desired activation of a specific muscle or muscle group. Although some evidence has been published on lower and upper limb muscular activity in strength training exercises [5-10] some muscle groups have not yet been explored.

The glenohumeral joint exhibits the greatest amount of motion of any joint in the human body, which can result in instability to this joint. Hence, it is very important to strengthen the stabilizer muscles of the shoulder in order to increase stability. The deltoid is a triangular muscle composed of the anterior, medial, and posterior portions and can generate great torque at the shoulder [11,12]. Strengthening the specific deltoid portions is relevant to increase performance in many sports as well as to prevent shoulder injuries, since each portion of the deltoid muscle is responsible for specific movements or stabilization of the shoulder joint. Thus, knowing the effect of different exercises on the EMG activity of the three portions of the deltoid will permit selection of the correct exercise to strengthen and/or rehabilitate the shoulder. However, there is currently a lack of scientific evidence to determine which strength exercises are best in activating each deltoid portion.

Therefore, the present study aimed to measure EMG activity of the three portions of the deltoid (anterior, medial and posterior) and to compare them in eight different upper limb strength training exercises.

Methods

Subjects

Eight healthy male subjects (mean age = 23.4 ± 1.6 years, height = 177.2 ± 2.3 cm and mass = 78.9 ± 16.2 kg) with at least six months strength training experience and without injury in the upper extremities in the last year volunteered for this study. All volunteers were informed of the risks and benefits of participation and signed an informed consent prior to their participation. All procedures were performed according to the Helsinki declaration, and the investigation was approved by the Ethics Committee of the Federal University of Rio Grande do Sul (document number 2008006).

Procedure

The following eight strength training exercises were investigated in the current study: free weight bench press, smith machine shoulder press, peck deck, reverse peck deck, free weight lateral raise, cable crossover lateral raise, incline lat pull-down, and seated row. These exercises were chosen because they involve the deltoid muscle and are commonly used in strength training programs. The exercises were performed as described in Baechle et al. [1] with minor changes for the incline lat pull-down and seated row. For the incline lat pull-down, subjects were seated on the machine and stayed in a posterior tilt position so that the cable of the machine was perpendicular to their body. For the seated row, subjects were seated straight upright with a pronated grip and their shoulders abducted to 90°; the exercise was done by performing a horizontal shoulder extension and elbow flexion for the concentric phase of the movement. The reverse peck deck was not described in the cited reference [1]. This exercise was performed with a neutral grip and elbows straight, while performing horizontal shoulder extension for the concentric phase of the movement. All machines used in the study were from a local fitness company (Sculptor, Brazil).

In the two first sessions, the 10RM load for each subject was determined for each exercise. The 10RM load was determined as the weight that allowed subjects to perform only 10 repetitions with proper technique and cadence. The 10RM loads were determined by trial and error with a 2:2 metronome controlled cadence (two seconds concentric and two seconds eccentric). If the subject was able to complete more than 10 repetitions with a weight, a new trial was performed 10 minutes afterward, with a readjusted load. No more than 3 trials were performed for an exercise in each session, and all exercises were randomized between test sessions through a simple raffle.

Forty-eight hours after the last 10RM session, subjects had their deltoid surface electromyography data assessed in maximal voluntary isometric contractions (MVIC). The anterior deltoid EMG signal was collected during shoulder flexion, while the medial and posterior deltoid EMG signals were collected during horizontal shoulder extension. All MVICs were performed unilaterally with the subject's dominant arm in an instrumented cable crossover device. A load cell (Miotec – Equipamentos Biomédicos, Brazil) was fixed between the ground and the weight stack. Volunteers held tightly to the cable handle and were instructed to exert "as much force as possible" during each MVIC. Verbal encouragement was provided for all subjects [9]. Three five-seconds MVICs were performed for shoulder flexion and for horizontal shoulder extension in randomized fashion with a five minute rest interval. For shoulder flexion MVIC, the shoulder joint position was set at 90° of flexion (0° refers to the arm beside the body), and for horizontal shoulder flexion, the shoulder joint was positioned at 90° of abduction. In both MVIC conditions, the subject's elbow was completely extended, the radioulnar joint was fixed at a neutral position, and the angle between the subject's hand and the cable was 90°. These MVIC positions were previously found to be the most appropriate positions for determining EMG activation of the three portions of the deltoid in a pilot study in our laboratory.

In the two final sessions, EMG signals of the deltoid were collected during performance of each strength exercise in randomized fashion with a 10RM load. Between sessions rest was 48 hours, and the same rest was given between the first session and MVIC test. An 8-10 minute rest interval was given between exercises, and only four exercises were performed in each session. All exercises were performed with a 2:2 metronome controlled cadence, as previously described.

Instrumentation

Silver chloride bipolar surface electrodes connected to a preamplifier and a 2000 Hz electromyograph system (Miotec - Equipamentos Biomédicos, Brazil) were used to collect EMG data. The load cell was directly connected to the EMG system. The EMG system was connected to a microcomputer that allowed visualization of the signal in real time. The EMG signal was synchronized with the force-time curve obtained by the load cell in the MVIC test. To identify each repetition, a displacement transducer (Miotec - Equipamentos Biomédicos, Brazil) was positioned on the weight, and the signal from the transducer was synchronized with the electromyography system.

After shaving and cleaning the skin with an alcohol-soaked pad, the electrodes were positioned in each deltoid portion according to SENIAM (seniam.org), and the reference electrode was positioned on the subject's clavicle. The impedance level was controlled below 3000 Ohms, and the distance between the centers of the electrodes was 20 mm. Individual maps were made to ensure that the electrodes were correctly repositioned [14].

EMG signal analysis

Raw EMG signals were stored on a personal computer for further treatment and analysis in the Sistema de Análises de Dados 32 software (SAD 32 - developed by the Engineering School of the local university). All EMG signals were filtered with a five order Butterworth band-pass filter, with a cutoff frequency between 20Hz and 500Hz. After filtering, EMG signals obtained in the MIVC were sliced in one-second sections according to the force-time curve plateau of the greatest MVIC and the RMS value was obtained. To quantify muscular activation of the three portions of the deltoid during each strength exercise, RMS values obtained in the second, fourth, sixth and eighth repetitions of each exercise passed through the same EMG treatment described above, and the mean value of these four repetitions were normalized to the signals obtained in the MVIC test. The start and end of the repetitions were visually determined in the SAD32 software, through use of the displacement transducer curve. Normalized mean values, in MVIC percentage, of the four analyzed repetitions were used to express muscular activation of each portion of the deltoid across the eight exercises [6,15].

Statistical Analyses

All measures are reported as mean and standard deviation (SD). The Shapiro-Wilk test was used to verify a normal distribution of the data. Normalized EMG activation of the three portions of the deltoid in each exercise were analyzed with repeated measures ANOVA, and a Bonferroni post hoc test was used to identify differences in activation between exercises for each portion. All data analyses were performed using SPSS 16.0 software, and the significance value was set *a priori* at $\alpha < 0.05$.

Results

Activation of the anterior deltoid did not differ significantly between smith machine shoulder press (70 ± 12.8%), bench press (56.5 ± 3%) or peck deck (49.7 ± 13,9%) ($P > 0.05$) but showed greater activation in the smith machine shoulder press when compared with the free weight lateral raise, cable crossover lateral raise, reverse peck deck, seated row and inclined lat pull-down (≈10-40%) ($P < 0.05$) (Fig. 1).

The free weight lateral raise (54.4 ± 16.3%), cable crossover lateral raise (53.4 ± 16.4%), reverse peck deck (47.1 ± 19.5%), and seated row (40 ± 14.5%) demonstrated similar medial deltoid activation ($P > 0.05$). However, the free weight lateral raise resulted in greater activation than the shoulder press, inclined lateral pull-down, bench press and peck deck (≈10-40%) ($P < 0.05$) (Fig. 1).

For the posterior deltoid, the reverse peck deck (91.1 ± 39%), incline lat pull-down (57 ± 29%), and seated row (53.6 ± 22.8%) were not significantly different, but the reverse peck deck resulted in greater activation than the cable crossover lateral raise, free weight lateral raise, bench press, shoulder press and peck deck (≈10-40%) ($P < 0.05$) (Fig. 1).

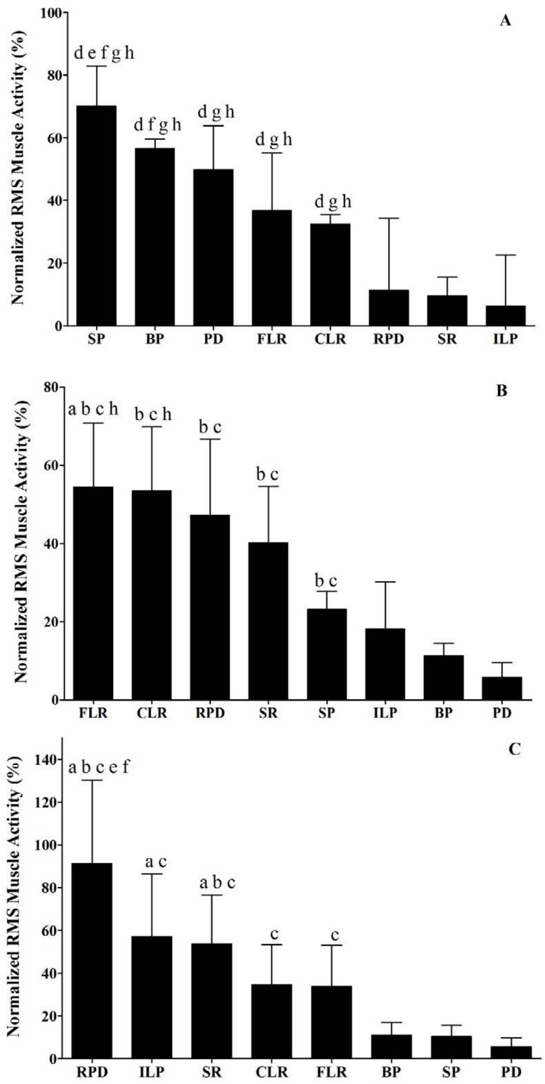

Fig. 1. *Relative activation (% normalized RMS values) of the anterior portion (A), medial portion (B) and posterior portion (c) of the deltoid across strength exercises (mean and standard deviation). SP = shoulder press; BP= bench press; PD = peck deck; FLR = free weight lateral raise; CLR = cable crossover lateral rise; RPD = reverse peck deck; SR = seated row; ILP = incline lat pull-down. The letters represent significant differences (P < 0.05): a significantly greater than SP, b significantly greater than BP, c significantly greater than PD, d significantly greater than RPD, e significantly greater than FLR, f significantly greater than CLR, g significantly greater than SR, h significantly greater than ILP.*

Discussion

The results of this study demonstrate that each portion of the deltoid is activated differently per specific exercise. This occurs even if the exercises are not specific to the shoulder. This shows that the deltoid muscle is activated even when performing exercises involving other muscle groups such as multi-joint exercises. The main findings of the present study were that activation of the anterior deltoid was similar in the smith machine shoulder press, bench press and peck deck, and greater in the smitch machine shoulder press than in the other exercises; the medial deltoid showed similar activation during the reverse peck deck, seated row, free weight lateral raise and cable crossover lateral raise, and greater in the free weight lateral raise than in the other exercises; while for the posterior deltoid, the similar activation occurred during the reverse peck deck, seated row, and incline lat pull-down, and greater activation in the reverse peck deck than during other exercises.

Greater activation of the anterior deltoid can be explained by its main agonist movement (horizontal shoulder flexion) and by the joint stabilization function of this muscle during the bench press, and the peck deck [16,17]. For example, in the bench press exercise the increased EMG of the anterior deltoid probably reflects its contribution to both joint stabilization and to bar elevation, presumably because this muscle tends to resist external shoulder rotation [18].

An interesting result of the present study was that the smith machine shoulder press generated high activation of the anterior deltoid, even though the movement performed was shoulder abduction, not shoulder flexion or horizontal flexion, which are considered to be the primary functions of this muscular portion [17]. This may arise from the external shoulder rotation position that posteriorly dislocates the joint, favoring activation of this muscle during shoulder abduction. Moreover, according to Liu et al. [19], the moment arm of the anterior deltoid is larger (1.5 cm) when the shoulder is in external rotation than when it is in a neutral position (0 cm) with the joint in 0° of abduction. Thus, the external shoulder rotation position during the smith machine shoulder press could be responsible for the greater activation of the anterior deltoid observed in the present study.

The medial deltoid showed greater activation during the free weight lateral raise and in the cable crossover. These results are corroborated by the literature, which refer to shoulder abduction as the main function of this portion [17,20,21]. The medial deltoid is considered the greatest shoulder abductor due to its superior moment arm [22] and cross sectional area [11] in relation to the other shoulder abductor muscles. However, despite the lateral raise exercise involving a specific movement for the primary function of the medial deltoid, other exercises involving more muscle groups had similar activation.

In relation to the reverse peck deck and seated row exercises, the lateral raise did not cause different EMG activity of the medial deltoid. The sustained position of shoulder abduction in the seated row and reverse peck deck exercises requires isometric action of this portion of the muscle, especially to stabilize the joint. According to Boettcher et al [23], with 90° shoulder abduction, the alignment of the deltoid fibers promote a transarticular compressive force, acting to stabilize the joint. These data corroborate the findings of the present study for the medial deltoid.

The posterior deltoid showed its largest activation when subjects performed the reverse peck deck, seated row, and the incline lat pull-down. This finding confirms that this muscular portion is the primary mover during horizontal shoulder extension (17). The lateral raise resulted in similar EMG signals of this portion when compared to the seated row and the incline lat pull-down. This can be explained by its secondary function in shoulder abduction, a movement performed dynamically in the lateral raise and isometrically in the incline lat pull-down and the seated row. Moreover, another important aspect to be considered is that the posterior deltoid collaborates to stabilize the movements when the shoulder is abducted [23], as is the case in the incline lat pull-down and the seated row.

Therefore, the results of the present study demonstrate that the deltoid muscle is activated similarly in specific exercises for the shoulder and in multi-joint exercises that involves more than one muscle group. Thus, analysis of muscular activation of the different upper limb strength exercises enables adequate selection and prescription of these exercises in order to vary the training stimulus for a specific muscular portion during training or rehabilitation programs.

Declaration of interest

The authors report no conflicts of interest.

References

1. Baechle TR, Earle RW. *Essential of strength training and conditioning*. Champaing: Human Kinetics, 2008.
2. Kraemer WJ, Ratamess NA. Fundamentals of resistance training: progression and exercise prescription. *Med Sci Sports Exerc* 2004; 36: 674-88.
3. Kraemer WJ. Exercise prescription in weight training: Manipulating program variables. *Natl Str* Cond Assoc J 1983; 5: 58-9.
4. Bird SP, Tarpenning KM, Marino FE. Designing resistance training programmes to enhance muscular fitness. *Sports Med* 2005; 35: 841-851.
5. Welsch EA, Bird M, Mayhew JL. Electromyographic activity of the pectoralis major and anterior deltoid muscles during three upper-body lifts. *J Strength Cond Res* 2005; 19: 449-52.
6. Escamilla RF, Fleisig GS, Zheng N, et al. Effects of technique variations on knee biomechanics during the squat and leg press. *Med Sci Sports Exerc* 2001; 33: 1552-66.
7. Wright GA, Delong TH, Gehlsen G. Electromyographic activity of the hamstrings during performance of the leg curl, stiff-Leg deadlift, and back squat movements. *J Strength Cond Res* 1999; 13: 168-74.
8. Trebs AA, Brandenburg JP, Pitney WA. An electromyography analysis of 3 muscles surrounding the shoulder joint during the performance of a chest press exercise at several angles. *J Strength Cond Res* 2010; 24: 1925-1930.
9. Jakobsen MD, Sundstrup E, Andersen CH, et. al. Evaluation of muscle activity during a standardized shoulder resistance training bout in novice individuals. *J Strength Cond Res* 2012; 26: 2515-2522.

10. Leslie KLM, Comfort P. The effect of grip width and hand orientation on muscle activity during pull-ups and the lat pull-down. *Strength Cond J* 2013; 35 (1): 75-8.
11. Bassett RW, Browne AO, Morrey BF, et al. Glenohumeral muscle force and moment mechanics in a position of shoulder instability. *J Biomech* 1990; 23: 405-15.
12. Lugo R, Kung P, Ma CB. Shoulder biomechanics. *Eur J Radiol* 2008; 68: 16-24.
13. Fischer SL, Belbeck AL, Dickerson CR. The influence of providing feedback on force production and within-participant reproducibility during maximal voluntary exertions for the anterior deltoid, middle deltoid, and infraspinatus. *J Electromyography Kinesiol* 2010; 20: 68-75.
14. Narici MV, Roi GS, Landoni L, et al. Changes in force, cross--sectional area and neural activation during strength training and detraining of the human quadriceps. *Eur J Appl Physiol Occupl Physiol* 1989; 59: 310-9.
15. De Luca CJ. The use of electromyography in biomechanics. *J Appl Biomech* 1997; 13: 135-63.
16. Brum DPC, Carvalho MM, Tucci HT, et al. Electromyographic assessment of scapular girdle and arm muscles during exercises with fixed boundary and axial load. *Rev Brasil Med Esporte* 2008; 14: 466-71.
17. Rasch PJ, Burke RK. *Kinesiology and Applied Anatomy; The Science of Human Movement*. Philadelphia: Lea and Febiger, 1978.
18. McCaw ST, Friday JJ. A comparison of muscle activity between a free weight and machine bench press. *J Strength Cond Res* 1994; 8: 259-64.
19. Liu J, Hughes RE, Smutz WP, et al. Roles of deltoid and rotator cuff muscles in shoulder elevation. *Clin Biomech (Bristol, Avon)* 1997; 12: 32-8.
20. Kronberg M, Nemeth G, Brostrom LA. Muscle activity and coordination in the normal shoulder. An electromyographic study. *Clin Orthop Related Res* 1990; 257: 76-85.
21. Reinold MM, Wilk KE, Fleisig GS, et al. Electromyographic analysis of the rotator cuff and deltoid musculature during common shoulder external rotation exercises. *J Orthop Sports Phys Ther* 2004; 34: 385-94.
22. Kuechle DK, Newman SR, Itoi E, et al. Shoulder muscle moment arms during horizontal flexion and elevation. *J Shoulder Elbow Surg* 1997; 6: 429-39.
23. Boettcher CE, Cathers I, Ginn KA. The role of shoulder muscles is task specific. *J Sci Med Sport* 2010; 13: 651-6.

Accepted: June 12, 2013
Published: June 28, 2013

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