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**Article** *in* The Journal of sports medicine and physical fitness · June 2014

Source: PubMed



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J SPORTS MED PHYS FITNESS 2015;55:714-21

# Analysis of anterior, middle and posterior deltoid activation during single and multijoint exercises

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***Aim.*** **Although comparison between multi and single joint exercises has been conducted, there is insufficient evidence that these exercises could lead to different muscle activations. The aim of this study was to compare deltoid muscle activation during multi and single joint exercises.**

***Methods.*** **Twelve male participants (23.4±1.6 years) with at least one year of strength training experience were assessed performing inclined lat pull-down, reverse peck deck and seated row exercises. Surface electromyography was used to measure activation of anterior, middle and posterior portions of deltoid muscle during each exercise. Deltoid activation was recorded during maximum voluntary isometric contraction (MVIC) and during dynamic isoinertial exercises of ten maximum repetitions for inclined lateral pull-down, reverse peck deck and seated row.**

***Results.*** **There was no difference in activation of the anterior portion of deltoid muscle for any of the three exercises (P=0.08). The middle portion presented greater activation during the reverse peck deck (P=0.03) and during the seated row (P=0.03) compared to the inclined lat pull-down. For the posterior portion of deltoid muscle there was greater activation during the reverse peck deck (P=0.001) compared to the seated row and to the inclined lat pull-down.**

***Conclusion*****. Results indicate that reverse peck deck and seated row should be more appropriate for recruitment of the middle portion of the deltoid muscle than the inclined lat pull-down. Differently, the reverse peck deck should be primarily used rather than the seated row and the lat pull-down for recruitment of the posterior portion of the deltoid muscle.**

**Key words:** Electromyography - Resistance training - Shoulder - Deltoid muscle.

The deltoid is a pennated muscle that covers the shoulder joint by three portions that are recruited to move the humerus in relation to the scapula. The anterior portion is a prime motor during flexion and horizontal adduction of the shoulder, while the middle portion acts during abduction and horizontal abduction and the posterior portion is recruited during horizontal abduction.[1, 2] Apart from humerus motion, the deltoid resists to lower pulling forces applied to the upper limb, improving joint stability.[3-5]

An individual analysis of each portion of the deltoid indicated that the anterior deltoid has the greatest potential to joint destabilization.[3] Traditional exercises of strength training (*e.g.* bench press) have emphasis on the anterior deltoid by the predominance of horizontal adduction movement of the shoulder, which could provide a muscular imbalance between individual portions of the deltoid and increase joint instability. Therefore, strength training for the middle and posterior deltoid muscle could enhance its role in gaining shoulder stabilization.

Strength training exercises have been assessed to compare the use of single and multijoint exercises and their effects in muscle recruitment.[6-11] Information gathered from these studies provided evidence for improving strength training prescription and optimization of training programs.[12, 13] The option for multijoint exercises has been suggested for begin-

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Figure 1.—Inclined lateral pull-down exercise.

ners because they require greater inter-muscle coordination compared to single joint motions.[12, 14, 15]

Although differences in neuromuscular coordination may be expected comparing multi to single joint exercises, the literature shows inconclusive results about muscle activation. Major attention has been given to assess activation of lower limb muscles with conflicting findings from these studies.[6-8, 10] For the upper limb, only two studies had focus on the assessment of shoulder horizontal adductors (*i.e. pectoralis major* and anterior deltoid) with no differences in activation of these muscles comparing single to multijoint exercises.[9, 11]

Based on this scenario, it is very important to understand how different portions of the deltoid are activated in different exercises to establish a more grounded rehabilitation and conditioning program, and to date, no studies compared activation of the three portions of the deltoid during single and multijoint exercises involving shoulder horizontal abduction. Thus, the purpose of this study was to compare activation of the three portions of the deltoid muscle (anterior, middle and posterior) during single and multijoint shoulder horizontal abduction exercises.

## Materials and methods

This study compared the electromyographic activity (EMG) of the three portions of the deltoid (anterior, middle and posterior) in three different exercises (inclined lateral pull down, seated row and reverse peck deck). Participants performed tests of maximal voluntary isometric contraction (MVIC) and ten maximal repetitions. Then, the three exercises were performed with simultaneous acquisition of the EMG signals.

Twelve healthy male participants (23.4±1.6 years; 177.2±2.3 cm; 78.9±16.2 kg; 15.4±4.2 % body fat) familiarized with strength training (at least six months of training) without shoulder injury history have taken part in the study. To asses these informations, the participants answered a questionnaire applied provided by researchers. The study was approved by the University Ethics Committee in Human Research (2008006) and all participants signed an informed consent to take part in the study.

### *Procedures*

Data was collected during three sessions that were separated by 48 hours. During the first session, methods and procedures of the study were introduced to participants. Anthropometrics were then collected for participants' characterization. After that, muscle activation was collected using surface electromyography during three MVIC in the established positions, separated by five minutes of rest.

In the second session, participants performed ten maximum repetitions testing to estimate the load for each exercise (inclined lateral pull-down [Figure 1], seated row [Figure 2] and reverse peck deck [Figure 3]). Testing order was randomly selected and a resting interval of five minutes between trials was enforced. In the third session, participants performed the three exercises with the ten maximum repetitions load and simultaneous recording of muscle activation.

Figure 2.—Seated row exercise.

Figure 3.—Reverse peck deck exercise.



*MVIC*

MVIC were performed using a crossover exercise machine (World, Porto Alegre, RS, Brazil) instrumented with a load cell (Miotec - Equipamentos Biomédicos, Porto Alegre, RS, Brazil) in order to collect force measurements with simultaneous EMG records. Shoulder flexion was used to record the maximum force for the anterior portion of deltoid with participants in upright position and the dominant shoulder at 90° of flexion. Shoulder horizontal abduction was used to assess middle and posterior portion of deltoid maximum force, when participants were upright and the dominant shoulder were at 90° of abduction. In both positions, participants were instructed to pull the machine cable with their hand and to perform only the required movements, to try to minimize the contribution of other muscle groups. Participants were verbally motivated [16] (24) during the three trials of five seconds of each test and a five minutes resting interval was enforced to postpone fatigue effects.[17, 18]

*Ten maximum repetitions test*

Participants performed a ten maximum repetitions test to determine the load used in each exercise. Primarily, all participants warmed up in the target exercise with minimum self-selected load. The load for the ten repetitions test was changed until participants achieved exhaustion in the tenth repetition and was defined using the maximum of three trials. If a fourth trial of ten repetitions would be required, a new session was scheduled with the participants to avoid fatigue effects in load definition. A five minute rest was enforced between each ten repetitions trial.

The final loads obtained on the ten maximum repetitions tests were used in the exercises execution with the simultaneous acquisition of EMG signals. Order for performing the ten maximum repetitions tests and to record muscle activation during exercises was randomized.[19]

*Muscle activation acquisition and signal processing*

Surface electromyography was employed to measure the activation of the three portions of the deltoid muscle during maximum isometric contractions and during the inclined lat pull-down, reverse peck deck and seated row exercises. A four channel electromyography system (Miotool 400, Miotec - Equipamentos Biomédicos, Porto Alegre, RS, Brazil) was employed using bipolar configuration, sampling signals at 2KHz and 14 bits of resolution. Electrodes with 15mm radius (Kendall Mini Medi-Trace 100 - Tyco Healthcare, São Paulo, SP, Brazil) and 20 mm of centre-to-centre distance were attached to the skin on the muscle belly after careful shaving and cleaning of the area with an abrasive cleaner and alcohol swabs to reduce the skin impedance (lower than 3KW) [20] measured using a digital multimeter. Location for electrodes placement followed recommendation from SENIAM.[21] A reference electrode placed over the skin at the clavicle to act as a neutral site for the EMG signals. A transparent sheet was used to mark the position of the electrodes in relation to anatomical locations to reduce between-days variation in position of the electrodes.[20, 22]

EMG signals were exported from the data acquisition software (Miograph - Equipamentos Biomédicos, Porto Alegre, RS, Brazil) for offline analysis (SAD 32 - developed by the Engineering School of the local university). After gain compensation and off-set correction, a band-pass digital filter ($5^{th}$ order Butterworth with cut-off frequencies of 20-500Hz) was applied to the signals. A section of one second of the signal from each muscle was selected from the MVIC force measurement assessed by the load cell to compute the root mean square value (RMS) where force signal was steady and maximum. This value was then used for normalization of signals from the ten repetitions of each exercise.

The RMS of each muscle during the three exercises were computed for the second, fourth, sixth and eighth trials during both the concentric and eccentric phases of motion. A an optic motion tracking displacement sensor attached to the load cable of the exercise machine (Miotec - Equipamentos Biomédicos, Porto Alegre, RS, Brazil) was employed to define the start and end of each repetition and the concentric and eccentric phases of motion. An average of four RMS values was computed for each muscle during each exercise and converted to percentages of the MIVC.[23, 24]

*Statistical analysis*

Normality and sphericity of data distribution was assessed via Shapiro-Wilk and Mauchly tests, respectively. Correction factors of Greenhouse-Geisser were used whenever appropriate. A one-way ANOVA for repeated measures was used to compare deltoid muscle (anterior, middle and posterior portions) activation across exercises (seated row vs. inclined lateral pull-down vs. reverse peck deck). When between factors or interactions were found, a Bonferroni post-hoc analysis was performed. Results about participants' characterization are presented in the text as mean ± standard deviations and results about the load in ten maximum repetition tests and muscle activation in exercises in the figures as mean±standard errors. All statistical procedures were conducted in a statistical package (SPSS 17.0 for Windows, SPSS Inc., Chicago, IL, USA) and significance was assumed for $P<0.05$.

## Results

The load for the ten maximum repetitions test was significantly greater for the seated row compared to the inclined lateral pull-down ($P=0.01$) and to the reverse peck deck ($P<0.01$). The load during the inclined lateral pull-down was significantly greater than during the reverse peck deck ($P=0.002$) (Figure 4).

Significant differences in activation for the anterior portion of the deltoid were not observed comparing the three exercises ($P=0.08$) (Figure 5).

The middle portion of deltoid presented increased activation during the reverse peck deck and the seated row compared to the inclined lateral pull-down ($P=0.03$; $P=0.03$).

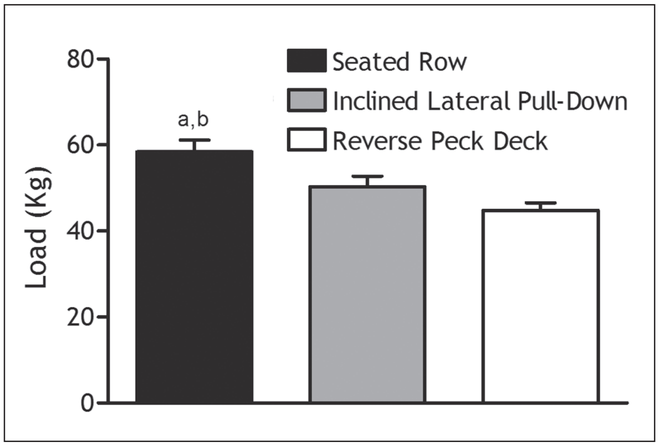


Figure 4.—Load (kg) from participants (mean±SEM) during the ten maximum repetitions test during the seated row, the inclined lateral pull-down and the reverse peck deck. [a]Significant differences to inclined lateral pull-down; [b]significant differences to the reverse peck deck (P≤0.05).

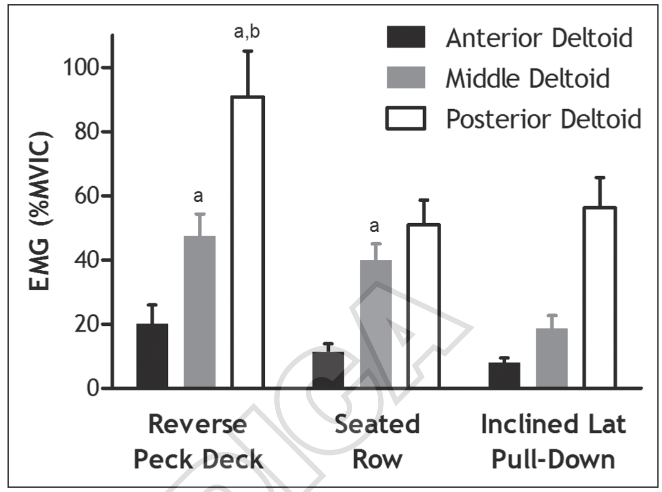


Figure 5.—Activation of the three portions of the deltoid (mean ± SEM) during the three assessed exercises. [a]Difference to the inclined lateral pull-down; [b]Difference to the seated row (P≤0.05).

For the posterior portion of deltoid, there was greater activation during the reverse peck deck compared to the seated row and to the inclined lateral pull-down (P<0.01), without differences between these last two exercises (P=0.22).

## Discussion

The main findings of this study were that: 1) the posterior portion of deltoid was largely recruited during the reverse peck deck (single joint exercise) compared to the seated row and inclined lateral pull-down (multijoint exercises); 2) the middle portion of deltoid was mostly recruited during the reverse peck deck and the seated row than during the inclined lateral pull-down; 3) the anterior portion of deltoid had minimal activation during the three exercises.

Various primary and secondary actions have been suggested for each portion of the deltoid muscle.[1, 2] Therefore, it is possible that the three portions of deltoid may be activated in opposite actions. For the anterior portion, it is intuitive to relate the low activations recorded in the three exercises to the role of this portion in shoulder flexion and horizontal adduction (opposite to the required actions). Ferreira *et al.*[25] observed that any exercise with focus on shoulder horizontal abduction elicited low levels from the anterior portion of the deltoid muscle, which is in line with our findings. The anterior deltoid activation can be justified as shoulder stabilization strategy via coactivation [26] and low activation levels (under 20% of MVIC) are in agreement with values reported in the literature.[27] Moreover, the level of co-activation of the anterior deltoid was not modified during single and multijoint exercises, which suggests the same level of joint instability during the performance of both types of exercises.

Differences comparing the inclined lateral pull-down to the reverse peck deck and the seated row may be due the single joint characteristic in the reverse peck deck and a double action required (shoulder isometric abduction and horizontal abduction) in the seated row. The greater activation for the posterior deltoid in the reverse peck deck could be explained by a restricted motion for the shoulder joint compared to the inclined lateral pull-down and seated row. Greater activation is required in single joint motion (compared to multi-joint) due the reduced number of muscles involved.[8] During multijoint exercises (*i.e.* inclined lateral pull-down and seated row) the larger external force observed in our study was potentially shared among elbow and shoulder joint muscles. Possibly, similar activation for middle portion of deltoid compared to the reverse peck deck was found at the seated row due the upper limb position. In this exercise, there is need for sustaining the upper arm at 90° of shoulder regular abduction in order to perform horizontal abduction by primary action of the middle and posterior portions of deltoid[1,2] and minimize the action of other muscles. That requires a double action from middle portion of deltoid (isometric abduction and dynamic horizontal abduction) which leads to comparable activation than single joint exercises (*e.g.* reverse peck deck), since whenever a muscle is required to perform two simultaneous actions, greater activation is required.[19] Differently, in the reverse peck deck and in the inclined lateral pull-down, gravitational force may not lead to an isometric action, due to the handles and position of the trunk and upper limbs, respectively.

A previous study showed similar activation levels comparing the machine chest fly (single joint exercise) to the bench press (multijoint exercise) [9] whilst another study observed greater activation for *vastus medialis* and *lateralis* during squats compared to knee extensions.[10] These studies compared exercises using free-weights (bench press and squat) to others performed in exercise machines with a lead for the resistive weight (machine chest fly and knee extensor machine). Free-weight exercises may require additional muscle activation to sustain body balance compared to exercise machines.[28-30] Thus, the increased activation for the free weight exercises may have similar activation level to the observed during exercises performed in machines, even for single joint exercises. Differently, in our study all exercises were performed in exercise machines and did not require additional muscle recruitment to sustain body balance, which may have elicited the larger muscle requirement to perform single joint than multijoint exercises.

Load can also be an intervenient factor in the results. Signorile *et al.*[10] justified the greater activation during squats to the greater load used in this exercise compared to the load used during knee extensions. In this case, the load and the exercise characteristic (free weight) contributed to greater activation. Although multijoint exercises are normally performed with greater loads, Junior *et al.*[9] showed greater load for the machine chest fly than the barbell bench press. In this study, the activation may have been favored by the load in the single joint exercise and by the free weight in the multijoint exercise, providing no significant difference between exercises. In the present study, the absolute load was greater in both multijoint exercises compared to the single joint exercise (all performed in machines) resulting in greater activation for the posterior deltoid in the single joint exercise.

Likewise, Welsch *et al.*[11] did not find differences in activation of *pectoralis major* and anterior portion of deltoid during barbell bench press, dumbbell bench press or dumbbell fly exercises. However, the authors indicated that differences in elbow flexion angle during the dumbbell fly execution may have led to discrepancies. An alteration in elbow flexion angle may have changed the resistant torque during the exercise and limited their results.

Apart from using machines with resistive weight guided by cables, the reverse peck deck machine employs a cam system. This system changes the moment arm of the resistive load throughout the range of motion and consequently the torque required to perform a single joint exercise, according to the muscle moment arms.[8, 31] To our knowledge, none of the previous studies referred to the use of cam system in single joint exercises machines, except for Enocson *et al.*,[8] who linked the greater muscle contribution to the existence of an eccentric pulley in the exercise machine, which enforces our results, since the conditions and results were similar.

To a certain level, our results could not be fully related to most studies because they had focus on lower limb exercises.[6-8, 10] Others assessed shoulder horizontal adductors during upper body exercises [9, 11] which is limited compared to our approach where assessments of the muscle group that acts in the shoulder horizontal abduction were conducted. Therefore, our study expands the existing knowledge in muscle function during strength training exercises.

Our option for using the maximum repetitions testing is because it is the most common choice in previous studies.[8-11] Another reason is the greater application for strength training prescription. However, an increased number of repetitions could lead to greater muscle activation due to fatigue effects in the EMG signals.[10, 17, 32] Previous studies with similar methods [6, 7] opted for using only two maximum repetitions to minimize fatigue effects. In these studies, leg press exercise and knee extensions performed in a machine did not differ in terms of quadriceps muscle activation, which may be explained by the reduced number of repetitions and consequently, minor fatigue influence, resulting in a different activation pattern. This is a possible reason to explain the fact that these studies did not found significant differences between single and multijoint exercises, unlike the present study.

However, it is speculated that muscle activation levels does not depend exclusively of single or multi-joint exercise characteristics. The number of actions performed by the same muscle in an exercise, the active muscle group and their mechanical properties, the characteristics of the exercise machine or equipment used, among other aspects may influence muscle recruitment. Thus, it is necessary to consider these aspects when comparing single and multijoint exercises.

## Conclusions

Our findings indicated that the seated row, the inclined lateral pull-down and the reverse peck deck leads to similar low levels of activation for the anterior portion of deltoid muscle due the fact that this portion has antagonist action in the assessed movements. On the other hand, seated row was effective in recruiting the middle portion of the deltoid muscle because they combine two primary actions of this muscle. The reverse peck deck was effective in recruiting the middle and the posterior portions of the deltoid muscle. This result provides evidence, for these exercises, that single joint exercises should optimize the contribution of less muscle mass and improve the contribution of each muscle, rather than a multijoint exercise when force is shared among more muscles.

For an advanced stage of training programs looking for improvements in strength for the middle and posterior portions of the deltoid, it is recommended the option for single joint exercises, rather than multijoint exercises. That should enhance gains in muscle strength compared to multijoint exercises.

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*Funding.*—The authors would like to thank Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES-Brazil) and Conselho Nacional de Pesquisa (CNPq-Brazil) for financial support and all volunteers for their participation in this project.

*Conflicts of interest.*—The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Received on September 11, 2013.
Accepted for publication on June 18, 2014.

Epub ahead of print on June 20, 2014.