Influence of Different Ranges of Motion on Selective Recruitment of Shoulder Muscles in the Sitting Military Press: An Electromyographic Study

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Abstract

Paoli, A, Marcolin, G, and Petrone, N. Influence of different ranges of motion on selective recruitment of shoulder muscles in the sitting military press: an electromyographic study. *J Strength Cond Res* 24(6): 1578–1583, 2010—Popular fitness literature suggests that varying the elbow range of motion (ROM) during the Military press can lead up to specific muscle isolation especially for deltoid and trapezius muscles. The purpose of the study was to examine the effect of ROM at different loads on the electromyographic (EMG) activity of 8 preselected muscles. Six experienced lifters performed 3 sets of 10 repetitions, each one with a different ROM: the first one with a final elbow angle of 90° (R1); the second with 135° (R2), and the last one with a final elbow angle of 180° (R3). Three resistances were chosen (no load, 30% of one repetition maximum [1-RM], and 70% of 1-RM), and sets were separated by 5 minutes rest. Electromyographic surface electrodes were placed on the clavicular head of pectoralis major, anterior deltoid, medial deltoid (MD), posterior deltoid (PD), upper trapezius, middle trapezius (MT), long head of triceps, and teres minor (TM). Analysis of variance showed a significant increase of rmsEMG activation with the widest ROM for each muscle and for each load condition except in MT and TM and PD with no load. The results showed that the use of the widest ROM increased the EMG activity of all the muscles selected with respect to the closest one, whereas this effect is not totally confirmed with the employment of R2. In addition, the use of intermediate ROMs was able to isolate the activity of the MD with respect to the trapezius only in the condition of the heaviest load. This suggests to coaches that in strength development programs the employment of an incomplete ROM can reduce the involvement of the trapezius without decreasing medium deltoid activation only with heavy loads.

Key Words muscle activity, muscle isolation, resistance training

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Introduction

Needle and surface electromyography as methods to investigate muscle functions are well known since the mid-1900s, and they are both employed for investigations on normal and pathological muscles. Nowadays, surface EMG, above all because of its noninvasive characteristic, has a growing application also in sports to better understand timing of muscle activations in specific disciplines or muscle activation selectivity in different fitness and rehabilitation exercises and in variants of the same exercise.

Electromyographic investigation of shoulder muscles was employed to develop specific rehabilitation protocols of glenohumeral and scapulothoracic muscles (9,11) and also to examine shoulder muscle activity during overhead sport activities (5) where injuries of the rotator cuff are very common together with disorders of biceps tendon and pectoralis major. Recently, there is also a growing interest in the effect of exercise-technique variation on muscle pattern activity in several fitness and training exercises for the development of upper-body muscles. Cogley et al. (4) compared the EMG activity of pectoralis major and triceps brachii during the push-up exercise using various hand positions suggesting that, if the goal is to increase muscle activation, a narrow hands base position should be chosen rather than a wide hands base position. Signorile et al. (10) investigated the effects of different hand positions on the EMG activity of preselected shoulder muscles during the lat pull-down showing that changes in handgrip position affected the activities of specific muscles. In particular, the wide grip hand was demonstrated to be the best one for the latissimus dorsi activation during both the concentric and the eccentric phases. Welsch et al. (12) examined the electromyographic (EMG) activity of the pectoralis major and anterior deltoid (AD) in terms of activation levels and time of activations during 3 different upper-body lifts. Results indicated that there was no significant difference for motor units activations, whereas dumbbell flies had significantly less relative time of activation than the other 2 lifts analyzed. Lehman (8) investigated the effect of grip width and forearm pronation/supination on upper-body muscles during the flat bench-press exercise showing that both these 2 variables can influence EMG activity of the muscles under investigation (sternoclavicular and clavicular portions of pectoralis major, biceps brachii, and the lateral head of triceps brachii).

Even if the sitting military press exercise is often included in training programs for the strength development of shoulder and arm muscles, just few studies analyzed this exercise from an EMG point of view. Büll et al. (2) studied the trapezius and the serratus anterior EMG activation during the execution of 4 different modalities of military press with open grip showing that trapezius acted significantly during standing and sitting press with the bar behind the neck, whereas serratus anterior acted significantly in all the modalities. In an other study, Büll et al. (3) analyzed the effect of the grip (middle or open) on several military press variants (standing, sitting, with the bar behind or in front of the neck). Results showed no significant differences in the muscle activation of trapezius and serratus anterior between open and middle grip.

In view of the previous investigations and of the variables analyzed, we decided to focus our attention on the EMG activation of shoulder and arm muscles during the execution of the sitting military press with dumbbells. In particular, we aimed to verify if different ranges of movement (ROMs) of the exercise led up to specific muscle isolation as reported in fitness handbooks. We decided to employ submaximal loads (0% of one repetition maximum [1RM], 30% of 1-RM, and 70% of 1-RM) to avoid possible nonvoluntary technique changes during the last repetitions of each set because of fatigue because of heavy load as reported by Duffey and Challis (6).

Thus, the purpose of our study was to investigate the effects of 3 elbow ROMs at 3 submaximal loads on EMG activity of 8 shoulder muscles with regard to the levels of EMG activity and to muscle isolation during the sitting military press with dumbbells.

Methods

Experimental Approach to the Problem

The sitting military press exercise with a complete elbow extension is often employed in fitness and training programs to develop shoulder and arm muscles. A variation of this exercise included an incomplete elbow extension with a reduced ROM with the aim of activating only specific muscles. To verify this theory, in the present study, we chose 3 ROMs (independent variable) with elbow angles, respectively, of 90° (R1), 135° (R2), and 180° (R3), as shown in Figure 1, and 3 dumbbells loads (independent variable) that were 0% and 30% of 1-RM, representative of the loads most employed by beginners and women, and 70% of 1-RM because these were often selected in sport-training programs. Six testers performed the sitting military press in the 3 ROM conditions with the 3 preselected loads in a randomized order and with specific rest pauses. The surface EMG of 8 shoulder and arm muscles (dependent variable) was recorded for each tester in 1-day session to avoid a change in EMG raw signal output because of a repositioning of the EMG probes. This experimental design allowed us to identify the

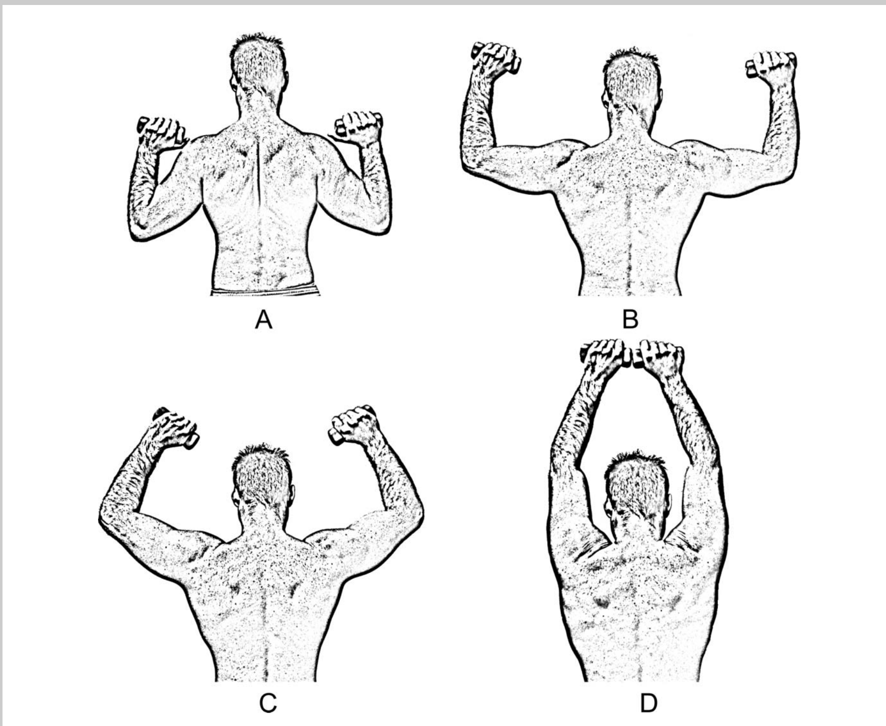

Figure 1. Ranges of motion (ROMs) examined during the sitting military press: (A) starting position, (B) incomplete ROM R1, (C) intermediate ROM R2, and (D) complete ROM R3. Each subject performed the exercise with dumbbells and with palms forward.

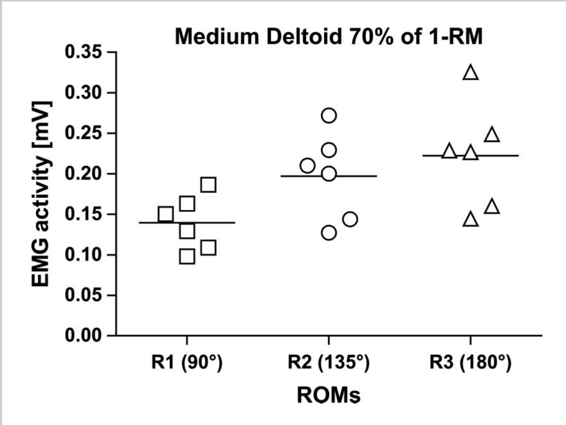

Figure 2. Effect of the 3 ROMs at 70% of one repetition maximum on the medium deltoid of the 6 subjects. Each mark is the mean value of the repetitions performed in each set excluding the first and the last one. The Horizontal solid lines represent the mean value for each ROM among the subjects.

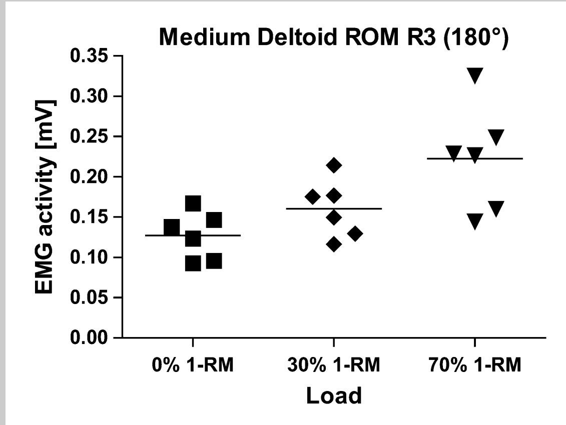

Figure 3. Effect of the 3 loads with ROM R3 on the medium deltoid of the 6 subjects. Each mark is the mean value of the repetitions of each set excluding the first and the last one. The Horizontal solid lines represent the mean value for each load among the subjects.

effect of the elbow ROMs and of the dumbbell loads on the EMG activity of the 8 muscles selected and on the selective recruitment of shoulder muscles.

Subjects

Six men with at least 3 years of lifting experience were involved in the study. They were not professional body builders, and they trained 3 times a week. They participated in the study in the same period of the year and were therefore of the same training status. Their mean age was 25.8 ± 3.7 years; mean weight was 78.8 ± 8.8 kg; and mean height was 181.5 ± 4.3 cm. Each subject did not report any shoulder injury or pathology at the moment of the experiments and during the previous 6 months. The study was approved by the Ethics committee of the Anatomy and Physiology Department of the University of Padova, and all participants were asked to read and sign an informed consent about the tests.

Procedures

The protocol was divided in 2 sessions: In the first one, each participant was familiarized with the exercise protocol and identified his own 1-RM load. The 1-RM was determined by increasing the dumbbell weight at each lift, until the subject could not perform the lifting in all its range of motion. In the second session, each subject performed a standardized warm-up consisting of shoulder stretching, shoulder mobility exercises, and some liftings with light load. They were then asked to perform the following trials: 3 sets (0%, 30%, and 70% of 1-RM) of 10 repetitions with elbow angle equal to 90° (R1, Figure 1B), 3 sets of 10 repetitions with an elbow angle equal to 135° (R2, Figure 1C) and finally 3 sets of 10 repetitions with a complete range of motion where the elbow angle was equal to 180° (R3, Figure 1D). The starting position and the starting elbow angle were the same for each trial of each set (Figure 1A). The rest was 5 minutes between trials with a further rest of 3 minutes between the sets. For each subject, all trials were randomized and performed in a 1-day session.

Electromyographic activity of 8 muscles of the right shoulder was recorded by means of a Muscle Lab® 4100e (Europe Ergotest, Boscosystem srl, Rieti, Italy). Muscles analyzed were clavicular head of pectoralis major (PMCH), AD, medium deltoid (MD), and posterior deltoid (PD), upper trapezius (UT), middle trapezius (MT), long head of triceps (TBLH), and teres minor (TM). Bipolar surface electrodes were placed on the muscular bellies along the direction of the fibers: distance between each couple of electrodes was 25 mm. The MuscleLab system converted the amplified EMG raw signal to an average root mean square (rms) signal via its built in hardware circuit network (frequency response, 450 kHz; averaging constant, 100 milliseconds; and total error ± 0.5%). Surface electrodes were chosen because they are painless and not invasive. Furthermore, Basmajian and DeLuca (1) specifically recommended surface electrodes when the level of EMG activity in large superficial muscles has to be examined. The skin over each muscle was shaved, scratched with abrasive paper, and finally cleaned with alcohol to reduce impedance values. An electrical goniometer (Boscosystem srl; sampling rate 100 Hz) was also fixed in the right elbow: Its signal and EMG signals were synchronously recorded. The signal of the electrical goniometer was visualized in real time on a monitor in front of the subject allowing him to reach the right elbow angle with high accuracy. Analysis of EMG records was based on every set of lifting with the exception of the first and the last repetition for a total of 8 repetitions for each set. The root mean square (rmsEMG) of the amplitude of the EMG for all the muscles was calculated with no distinction between eccentric and

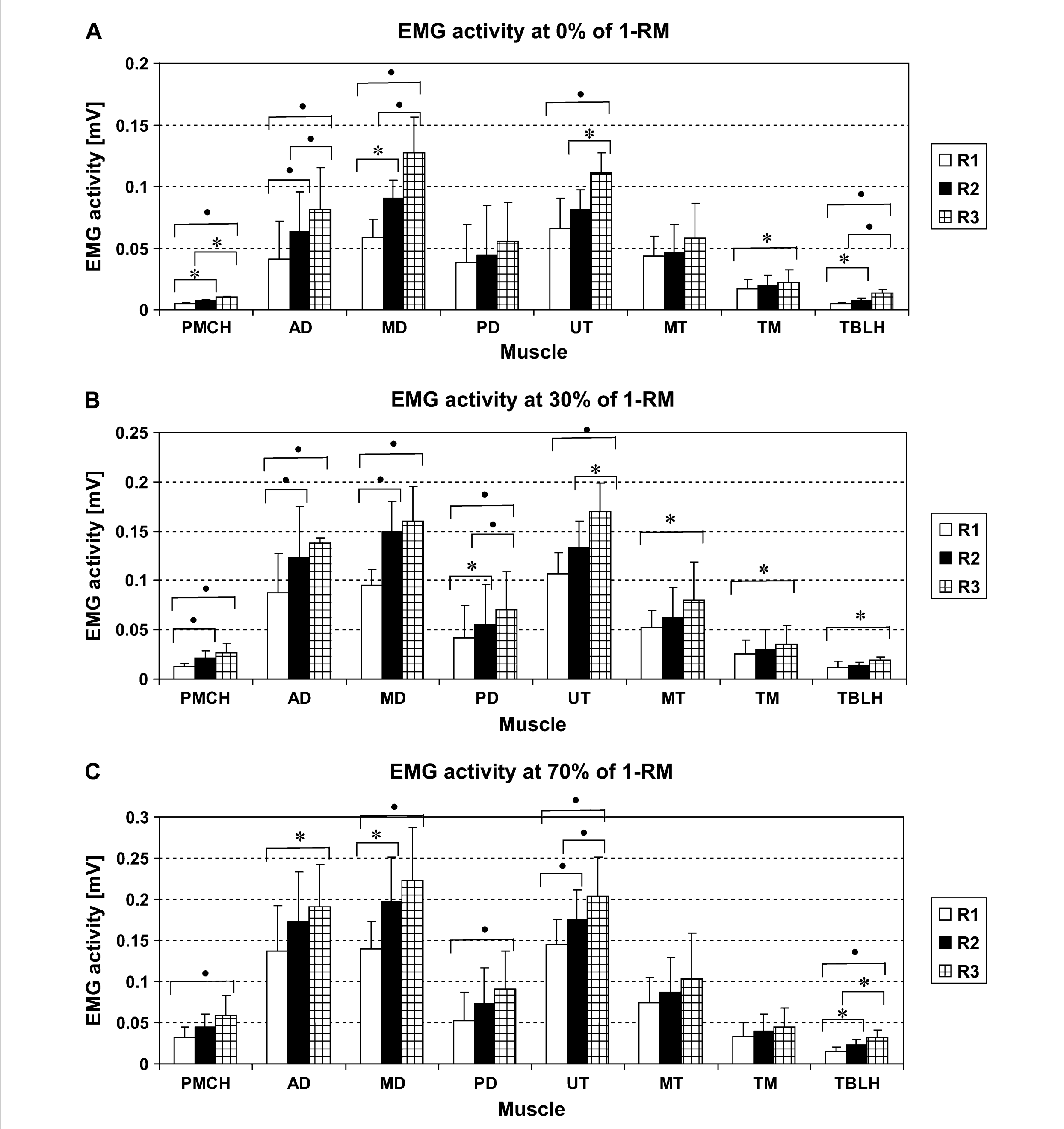

Figure 4. Electromyographic activity of the 8 preselected muscles with the 3 ROMs (R1, R2, and R3) at 0% of 1-RM (A), 30% of 1-RM (B), and 70% of 1-RM (C). Six nonprofessional body builders performed a set of 10 repetitions for each load and ROM condition. Mean and *SD*s of the means are presented: the first and the last repetition of each set were not considered for the analysis; *Significant differences ($p < 0.05$); ●Significant differences ($p < 0.01$). Abbreviations used: PMCH, Clavicular Head of Pectoralis Major; AD, Anterior Deltoid; MD, Medial Deltoid; PD, Posterior Deltoid; UT, Upper Trapezius; MT, Medial Trapezius; TM, Teres Minor; and TBLH, Long Head of Triceps.

concentric phases. In each set, the mean of rmsEMG of each lifting was made. Then the mean of the means was calculated.

Statistical Analyses

Data are expressed as mean and *SD*s. One-way analysis of variance for each independent variable (muscle, ROM, and dumbbell load) was used to analyze differences in the rmsEMG. Differences in levels of muscular activity were assessed for statistical significance ($p \leq 0.05$) and then, if appropriate, a Scheffè post hoc test was calculated.

Results

In this study, the level of activation of 8 different shoulder muscles during sitting military press was studied in 6 subjects in relation to the load and to the elbow angle. Figures 2 and 3 show the effect of changing the angle (ROM) with a constant load (70% 1-RM) or changing the load with a constant angle (ROM R3 corresponding to a final angle of 180°) on the activation of the Medium Deltoid in 6 subjects. As explained in the Methods, each data point is the average of the 8 repetitions. Despite interindividual differences, consistent trends are detectable for this specific muscle (Medium Deltoid) and for the other muscles, giving support to a comparison between averages of the values obtained in each subject.

The whole comparison of the activity levels of the 8 muscles at the 3 ROMs (R1, R2, and R3) with 3 distinct loads (0%, 30%, and 70% of 1-RM) is shown in Figure 4. In particular, the results obtained with 3 distinct ROMs and no load (0% of 1-RM) are shown in Figure 4A. The activity was measured by calculating rmsEMG from surface EMG as described in the Methods. The mean rmsEMG values for the PMCH, AD, MD, TBLH with no load turned out to differ significantly in relation to different elbow ROMs. In particular, the level of EMG activation for PMCH with R3 was higher than with R2 ($p \leq 0.05$; Effect size $r = 0.72$; Power = 0.64) and R1 ($p \leq 0.01$; Effect size $r = 0.9$; Power = 0.95); also, the EMG activity with R2 was higher than with R1 ($p \leq 0.05$; Effect size $r = 0.68$; Power = 0.5). The AD was activated in R3 more than in R2 ($p \leq 0.01$; Effect size $r = 0.26$; Power = 0.84) and R1 ($p \leq 0.01$; Effect size $r = 0.52$; Power = 1), and in R2 more than in R1 ($p \leq 0.01$; Effect size $r = 0.33$; Power = 0.93). The MD activation was greater with R3 than both R2 and R1 ($p \leq 0.01$; Effect sizes $r = 0.62$ and 0.82; Powers 0.77 and 0.98), and it was also greater with R2 more than with R1 ($p \leq 0.05$; Effect size $r = 0.73$; Power = 0.68). The TBLH activation was greater with R3 than both R2 and R1 ($p \leq 0.01$; Effect sizes $r = 0.82$ and 0.92; Powers = 0.98 and 1), and it was also greater with R2 more than with R1 ($p \leq 0.05$; Effect size $r = 0.68$; Power = 0.52). The UT muscle activity was higher in R3 than in R2 ($p \leq 0.05$; Effect size $r = 0.67$; Power = 0.69) and R1 ($p \leq 0.01$; Effect size $r = 0.73$; Power = 0.91); no statistical differences were found between R1 and R2. For the TM, the only significant difference was found in R1 condition with respect to R3 with the greatest activation in this last condition ($p \leq 0.05$; Effect size $r = 0.3$; Power = 0.64). No significant differences were detected for the PD and the MT.

Figure 4B shows the EMG differences of the 8 muscles at the 3 ROMs with load equal to 30% of 1-RM. In this condition, the PMCH and AD level of EMG activation was higher with R3 more than with R1 ($p \leq 0.01$; Effect sizes $r = 0.7$ and 0.47; Power = 0.94 and 0.95), and with R2 more than with R1 ($p \leq 0.01$; Effect sizes $r = 0.59$ and 0.36; Power = 0.74 and 0.82); no statistical differences were detected between R2 and R3. The MD activation recorded with R3 was greater than the activation recorded with R1 ($p \leq 0.01$; Effect size $r = 0.76$; Power = 0.95); also, the difference recorded between R1 and R2 was statistically significant ($p \leq 0.01$; Effect size $r = 0.74$; Power = 0.9) with a greater muscle activation in the second condition. The PD EMG activity with R3 was greater than with R2 ($p \leq 0.01$; Effect size $r = 0.18$; Power = 0.73) and R1 ($p \leq 0.01$; Effect size $r = 0.37$; Power = 0.98); also, the activation with R2 was higher than with R1 ($p \leq 0.05$; Effect size $r = 0.18$; Power = 0.67). The UT muscle activity was higher in R3 more than in R2 ($p \leq 0.05$; Effect size $r = 0.56$; Power = 0.57) and R1 ($p \leq 0.01$; Effect size $r = 0.78$; Power = 0.91); no statistical differences were found between R1 and R2. For the MT, TM, and TBLH, the only statistically significant difference was detected between R3 and R1 ($p \leq 0.05$; Effect sizes $r = 0.43$, 0.35, and 0.59; Powers = 0.54, 0.67, and 0.65) with a higher activation in the R3 condition.

In Figure 4C, the graphical representation of EMG activity of the preselected muscles with the 3 ROMs at 70% of 1-RM is presented. The PMCH and PD activation showed significant differences only between R3 and R1 ($p \leq 0.01$; Effect sizes $r = 0.58$, 0.43; Powers = 0.81, 0.73) with the highest value with R3. For the AD, EMG activity with R3 was greater than that with R1 ($p \leq 0.01$; Effect size $r = 0.45$; Power = 0.66); no other significant differences were detected for this muscle. The MD level of EMG activation was higher with R3 more than with R1 ($p \leq 0.01$; Effect size $r = 0.62$; Power = 0.79), and with R2 more than with R1 ($p \leq 0.05$; Effect size $r = 0.54$; Power = 0.52); no statistical differences were detected between R2 and R3. The UT was activated in R3 more than in R2 ($p \leq 0.01$; Effect size $r = 0.31$; Power = 0.74) and R1 ($p \leq 0.01$; Effect size $r = 0.59$; Power = 0.99), and in R2 more than in R1 ($p \leq 0.01$; Effect size $r = 0.43$; Power = 0.82). The level of EMG activation for TBLH with R3 was higher than with R2 ($p \leq 0.05$; Effect size $r = 0.53$; Power = 0.7) and R1 ($p \leq 0.01$; Effect size $r = 0.75$; Power = 0.96); also, the EMG activity in R2 was higher than in R1 ($p \leq 0.05$; Effect size $r = 0.53$; Power = 0.5). No statistical differences were found for MT and TM.

Discussion

The results obtained in the present study showed that EMG activity of all 8 selected muscles increased, as expected, in rough proportion with the increase of the load. Moreover, the EMG analysis of the military press showed that the wider was the ROM, the higher was the rmsEMG of each muscle. In particular, for all the selected muscles, with the exclusion of the PD and MT at 0% of 1-RM, the MT and TM at 70% of 1-RM, where no statistical significance was detected, the complete ROM (R3) assured a greater activation with respect to R1, whereas the intermediate ROM R2 was in an intermediate position regarding the muscle level of activation. The choice of light and moderate loads allowed us to obtain consistency among repetitions and among sets in such a way that EMG muscle variation could be above all because of the

ROMs and not because of possible technique changes determined by fatigue as reported by Duffey and Challis (6) in bench-press exercise.

With regard to the possibility of muscle isolation, that is, specific activation of individual muscles obtained by varying the ROM of the sitting military press, our results showed how the trapezius and the deltoid were the most involved muscles in this exercise with each of the 3 ROMs, confirming the previous reports by Bull et al. (2,3) about trapezius electrical activity. Our study did not completely support the popular fitness literature indication that performing the military press with an incomplete ROM isolates the deltoid activity reducing the participation at the movement of the trapezius. In fact, only at 70% of 1-RM we recorded no significant differences in the whole deltoid activation (AD, MD, PD) between R2 and R3, while UT was more activated with R3 than with R2. This suggests that if the purpose is to reduce the participation of UT without varying the intensity of the deltoid activation, the intermediate ROM R2 should be chosen with intermediate heavy loads. For the other loading conditions, as explained above, the execution of a complete ROM (R3) elicited the greatest deltoid EMG activity together with the trapezius showing their synergic activation with the impossibility of reciprocal isolation. The decrease of deltoid EMG activity together with a parallel decrease of the trapezius activity suggests not to perform the military press with partial elbow ROM with the only exception of the heaviest loading condition (70% of 1-RM) where an intermediate ROM (R2) does not reduce EMG activity of the deltoid but significantly reduces UT electrical activity.

Practical Applications

The sitting military press is one of the most employed exercise for developing shoulder strength among athletes and recreational lifters. The results of our study showed that the highest EMG activity is obtained by performing the exercise with a complete ROM; so, if the primary purpose is the development of strength, incomplete ROMs should be avoided. Secondly, even if some fitness handbooks (7) report that an incomplete ROM could elicit the activation of the deltoid, our study does not agree completely with those statements. In fact, in all the conditions we tested, deltoid and trapezius were synergic muscles in the humerus abduction, and the only effect of the employment of incomplete ROMs was a decrease of their electrical activity. Only in the heaviest loading condition (70% of 1-RM), an intermediate ROM with respect to a complete one, did not significantly reduce the EMG activity of the whole deltoid with a significant reduction of UT electrical activity. This suggests that, in strength development programs with heavy loads, the choice of an incomplete ROM might reduce the involvement of the trapezius without decreasing deltoid activation.

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