An Electromyography Analysis of 3 Muscles Surrounding the Shoulder Joint During the Performance of a Chest Press Exercise at Several Angles

Arthur A. Trebs,[1] **Jason P. Brandenburg,**[2] **and William A. Pitney**[1]

[1]*Department of Kinesiology and Physical Education, Northern Illinois University, DeKalb, Illinois; and*
[2]*Department of Kinesiology and Physical Education, University of the Fraser Valley, Abbotsford, British Columbia, Canada*

Abstract

Trebs, AA, Brandenburg, JP, and 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* 24(7): 1925–1930, 2010—This study compared the activation of the clavicular head and the sternocostal head of the pectoralis major and the anterior deltoid when performing the bench press at several different angles. Fifteen healthy male subjects participated in this study. Subjects performed the chest press exercise at 0 (flat bench), 28, 44, and 56° above horizontal using 70% of their respective 1 repetition maximum for each angle. Electromyographic activity was recorded during each repetition. Activation of the clavicular head of the pectoralis major was significantly greater at 44° compared to 0° ($p = 0.010$), at 56° compared to 0° ($p = 0.013$), and at 44° compared to 28° ($p = 0.003$). Activation of the sternocostal head of the pectoralis major was significantly greater at 0° compared to 28° ($p = 0.013$), at 0° compared to 44° ($p = 0.018$), at 0° compared to 56° ($p = 0.001$), at 28° compared to 56° ($p = 0.003$), and at 44° compared to 56° ($p = 0.001$). Activation of the anterior deltoid was significantly greater at 28° compared to 0° ($p = 0.002$), at 44° compared to 0° ($p = 0.012$), and at 56° compared to 0° ($p = 0.014$). To optimize recruiting the involved musculature, it would seem that performing both the flat and incline chest press exercises is necessary.

Key Words strength training, resistance training, neuromuscular, electromyography

Address correspondence to Jason Brandenburg, jason.brandenburg@ufv.ca.

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Introduction

Resistance training is incorporated into training regimens to increase strength, muscular endurance, and muscle mass. The effectiveness of a resistance training program is dependent on a number of acute variables, one of which is exercise selection. In addition to determining the muscles that are used, exercise selection also influences the extent to which these muscles are activated. For example, different variations of an exercise affect how effectively a whole muscle or muscle group is stimulated.

Support for this was provided by Clemons and Aaron (4), who examined the differences in the myoelectric activity produced by the muscles involved in a bench press exercise when using different grip widths. They found that the widest grip produced the greatest amount of myoelectric activity among the muscles tested, whereas the narrowest grip produced the least amount of activity. Cogley et al. (5) found that a narrower than shoulder width hand position produced a significantly greater amount of myoelectric activity within the muscles tested than the wider than shoulder width hand position during a push-up exercise. Although the results of these studies seem to be contradictory, they support the idea that variations of an exercise differently stimulate the prime movers of the exercise.

The chest press exercise is a routinely performed upper body exercise used to develop the strength of the chest, shoulder, and triceps musculature (14). In addition to the flat bench chest press, a number of variations that alter the angle of bench incline are used despite a lack of clear understanding on how this modification alters activation of the pectoralis muscle group and other synergist muscles.

Glass and Armstrong (9) conducted a study aimed at determining the recruitment patterns of the clavicular and sternocostal portions of the pectoral muscles during an incline and decline press. They found that the sternocostal portion of the pectoralis major was more active during the decline press than during the incline press, whereas the clavicular portion of the pectoralis major was equally activated during both the incline and decline press. Likewise, Barnett et al. (2) collaborated on a study in which the purpose was to examine the myoelectric activity of the clavicular and sternocostal portions of the pectoralis major and the anterior portion of the deltoid during different variations of a barbell chest press. These variations included changes in the angle of the press: horizontal, vertical, 18° below horizontal (decline), and 40° above horizontal (incline). The sternocostal head of the pectoralis major was most active during the horizontal chest press and least active during the vertical press. Although the clavicular head of the pectoralis major showed a significant increase in activity as the angle of the press increased from the decline position to the incline position, this greater activity in the incline position was not significantly different from the horizontal position. In the vertical position, the activation of the clavicular head of the pectoralis major was significantly less than it was at the incline and horizontal positions. Overall, the activity of the anterior portion of the deltoid increased as the angle of the press increased (2).

Based on the findings of Glass and Armstrong (9) and Barnett et al. (2), it appears that variations in bench angle during the chest press affect the degree of activation of the involved muscles. Although the activation of the sternocostal portion of the pectoralis major seems to decrease as the angle of the bench increases, a clear trend for how the activation of the clavicular portion is altered is less evident. Perhaps the single angle of incline used in each of these studies (30° above horizontal by Glass and Armstrong [9] and 40° above horizontal by Barnett et al. [2]) may account for the absence of a trend. These angles may have been too small to significantly alter the activity of the clavicular head of the pectoralis major. Alternatively, it is possible that the angles of incline may have been too large; thus, changes in the activation of the clavicular portion of the pectoralis major were not detected. No matter what the explanation, to better understand how the different portions of the pectoralis major muscle group are influenced by bench angle, a systematic examination of muscle activity using multiple angles must be performed.

The degree of activation of a muscle or parts of a muscle elicited by an exercise is a key element in the stimulus for developing strength and muscle mass. Consequently, it would be beneficial to better comprehend the influence of changing the angle of bench incline of the chest press exercise on the activation of the pectoralis major muscle, specifically the clavicular and sternocostal portions. From a practical viewpoint, an improved understanding would aid in the selection of chest press variations that would be most effective at developing overall pectoralis muscle function.

The purpose of this study was to determine if there was a difference in the activation of the clavicular head and the sternocostal head of the pectoralis major and the anterior deltoid when comparing the horizontal bench press to an incline chest press performed at several different angles above horizontal.

Methods

Experimental Approach to the Problem

To determine if the angle of incline during the bench press influenced activation of the agonist muscles a repeated-measures, within subjects design was used. The 4 bench angles tested included the following: 0° (flat bench), 28° above horizontal, 44° above horizontal, and 56° above horizontal. Five repetitions, using a load of 70% of 1 repetition maximum (1RM) for that angle, were performed at each bench angle. Electromyography (EMG) activity of the clavicular and sternocostal heads of the pectoralis major along with the anterior deltoid was recorded, and later analyzed, at each angle.

Subjects

Complete data were collected from 15 male subjects (age = 24.5 ± 3.7 years, height = 180.6 ± 8.4 cm, weight = 88.0 ± 14.0 kg) who volunteered to participate in this study. At the time of data collection, subjects were regularly performing resistance exercise and had at least 1 year of resistance training experience. Subjects also had experience performing both the flat and incline bench press exercises and were able to bench press 100% of their body mass. Two other subjects were excluded based on this latter requirement. Subjects were required to be free from injury at the time of the testing and did not have a history of joint and muscular problems. Before data collection, subjects were provided information regarding the purpose and procedures of the study and then completed an informed consent document. Approval from the university's Institutional Review Board was provided before the commencement of this study.

Procedures

Subjects visited the laboratory on 2 different occasions. During the first visit, subjects were familiarized with the lifting procedures, and 1RM for each of the 4 bench press angles was measured. On the second visit, subjects performed a single set of 5 repetitions at each of the bench press angles using a load of 70% 1RM. The order in which the sets was performed was randomized and counterbalanced. During each of these sets, EMG was recorded from the sternocostal portion of the pectoralis major, the clavicular portion of the pectoralis major, and the anterior head of the deltoid.

One Repetion Maximum Procedures (Day 1 of Testing)

After a warm-up, subjects completed a 1RM test for each of the bench press angles to be tested: 0° (flat bench), 28° above horizontal, 44° above horizontal, and 56° above horizontal. The order of these tests was randomized for each subject. This order was recorded and repeated during the second day of testing. For 1RM testing and for all lifting, the subjects adhered to safe lifting techniques and used a closed, pronated grip. Subjects were allowed to self-select a comfortable hand spacing (at least shoulder width) to be used so long as it was consistently used for each lift and angle on both days. All testing sets (days 1 and 2) were completed using a Smith machine (without counterweight, Samson Equipment,

Table 1. Mean (±*SD*) 1RM and 70% of 1RM values for each bench angle.*

	Bench angle (°)			
	0	28	44	56
1RM (kg)	118.6 ± 30	105.3 ± 20	93.6 ± 19	85.1 ± 17
70% 1RM (kg)	83.3 ± 21	73.7 ± 14	65.4 ± 13	59.9 ± 12

*1RM = 1 repetition maximum.

Las Cruces, NM, USA), and as a result, the bar traveled vertically over the chest (in line with the nipple).

Preceding the 1RM testing, subjects completed 5 minutes of low-intensity cycling on a stationary cycle ergometer and then 1 set of 10 repetitions with all of the weight removed from the bar (25 kg) as a low-resistance, exercise-specific warm-up. These repetitions were performed at a cadence of a 1.5-second eccentric contraction followed by a 1.5-second concentric contraction and then a 1.5-second pause as measured by a metronome. This also served as practice for the cadence to be used during the testing on day 2.

Subjects then proceeded to their 1RM test at the respective angle being used. All 1RM attempts were concentric-only muscle actions and started from the safety stops on the Smith machine, which were set so the bar was positioned as close to the chest as possible without contacting the chest. The bar was vertically aligned over the nipples of each subject. Subjects began their 1RM attempts by pressing 50% of their subjective predicted maximum for each angle. This set was followed by sets of 75, 90, and 100% of their subjective predicted 1RM, respectively (1). If subjects successfully pressed 100% of their predicted 1RM, the weight was increased, and further attempts were made until a single repetition was not possible. The greatest amount of weight successfully lifted at one time was recorded as the subject's 1RM for the respective angle tested. Subjects were allowed up to 3 minutes of rest between each 1RM attempt and at least 5 minutes rest between each angle. Subjects were prompted to reach their 1RM with as few attempts as possible to avoid excess fatigue. For a 1RM lift to be considered valid, subjects had to achieve full extension at the elbow joints.

Data Collection (Day 2 of Testing)

Subjects were asked to refrain from any lifting or exertion with the upper body at least 48 hours before this test period. Subjects were first prepared for electrode placement. After this, each subject completed a 5-minute general warm-up on a stationary bike and then a more specific warm-up of 10 low-resistance (25 kg) bench press repetitions followed by the data collection sets at the 4 different bench angles. The order in which the bench press angles was tested was the same used for 1RM testing on day 1. For each of the data collection sets, subjects completed a set of 5 repetitions using a resistance of 70% of their 1RM for the particular angle being tested. All repetitions were performed to the cadence of a metronome with a 1.5-second eccentric contraction, a 1.5-second concentric contraction, and a 1.5-second pause in between repetitions. Range of motion for each repetition was from full elbow extension to within 2–3 cm of the chest, directly over the nipples. A 2-minute rest interval was provided between all sets. Additionally, subjects used the same grip type and grip width as they did on day 1.

During data collection, if subjects were unable to maintain the prescribed cadence of the lift they were asked to repeat the data collection trial on another day.

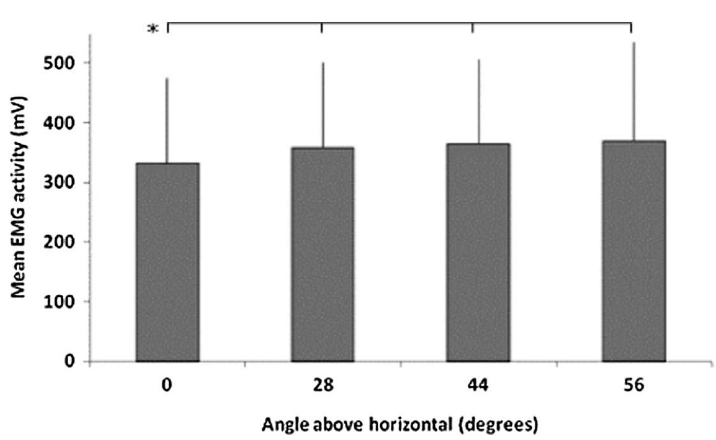

Figure 1. Mean electromyography activity produced by the anterior deltoid during the execution of a chest press performed at 4 different angles (* = significant differences between 0 and 28°, 0 and 44°, and 0 and 56°).

Electromyography Setup

Electromyography data were collected with a data acquisition unit (MP100, Biopac Systems, Inc, Goleta, CA, USA) from 3 muscles on the right side of the body: the sternocostal

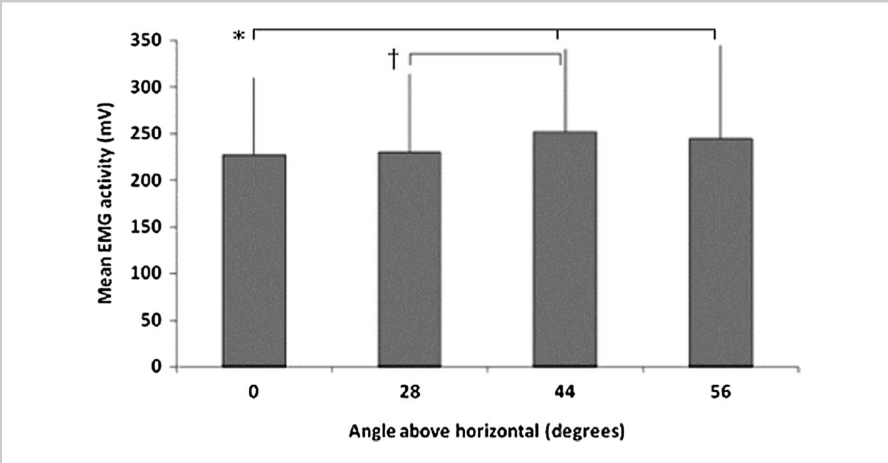

Figure 2. Mean electromyography activity produced by the clavicular head of the pectoralis major during the execution of a chest press performed at 4 different angles. (* = significant differences between 0 and 44°, 0 and 56°, and † = significant difference between 28 and 44°).

The electrodes for the anterior deltoid were aligned vertically below the lateral end of the clavicle over the midbelly of the anterior deltoid (3). A ground electrode was placed on a bony prominence within the area of the testing sites. This site included the sternal end of the clavicle, the sternum, or the anterior superior iliac spine. Before electrode placement, the recording areas were shaved, abraded, and wiped clean with an alcohol swab.

portion of the pectoralis major, the clavicular portion of the pectoralis major, and the anterior head of the deltoid. Two electrodes (pregelled Ag–AgCl, 10 mm, Biopac Systems Inc) were placed over the belly of each of these muscles with an interelectrode distance of 2 cm running parallel to the fibers and the direction of pull of the muscle being tested. To do so, the length of the clavicle was measured and the midclavicular point and the lateral edge of the clavicle were identified and marked. Recording electrodes for the clavicular portion of the pectoralis major were then placed on the midclavicular line over the second intercostal space, and the electrodes for the sternocostal portion of the pectoralis major were placed on the midclavicular line over the fifth intercostal space (9).

Electromyography data were collected during the concentric portion of the second, third, and fourth repetitions. Data were collected at 1,000 samples per second, high-pass filtered at 10 Hz and low-pass filtered at 500 Hz. Raw data were then stored on a personal computer for signal processing and analysis. The raw signal was smoothed and rectified to get a root-mean-square signal using Acknowledge 3.72 software (Biopac Systems, Inc). The average amplitude of the root-mean-square signal of the middle 3 repetitions at each bench press angle was used for analysis.

Statistical Analyses

A 2-way analysis of variance (ANOVA) was used to determine the effect of bench angle on the electrical activity of each muscle. When post hoc analysis was warranted, paired *t*-tests were used to determine the source of any significant results. The alpha level for all tests was set a priori at $p \leq 0.05$. The p value for any post hoc analysis was determined by dividing $p \leq 0.05$ by the total number of *t*-tests performed. This was done to avoid type II statistical error. Where there were differences, effect sizes (ESs) using Cohen's *d* were calculated (6). Interpretations of the ESs were based on Rhea's for highly trained subjects: <0.25 = Trivial, 0.25–0.50 = Small, 0.50–1.0 = Moderate, and >1.0 = Large (12).

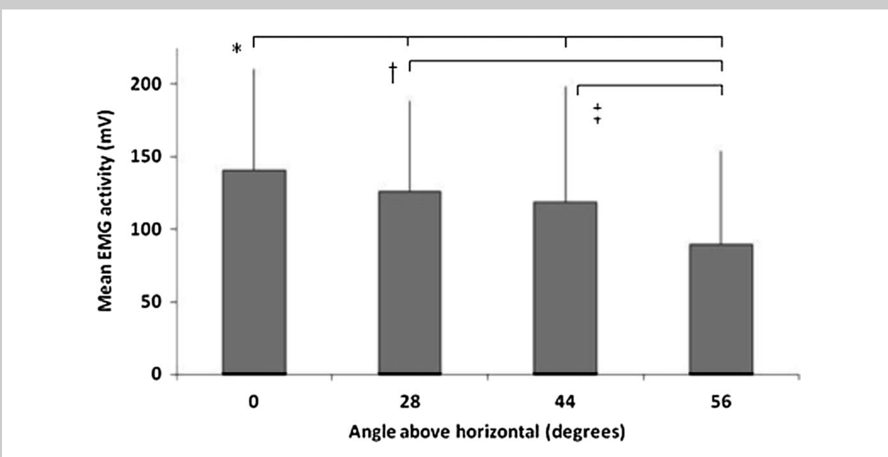

Figure 3. Mean electromyography activity produced by the sternocostal head of the pectoralis major during the execution of a chest press performed at 4 different angles (* = Significant differences between 0 and 28°, 0 and 44°, 0 and 56°, † = significant difference between 28 and 56°, and ‡ = significant difference between 44 and 56°).

Results

Loads Used

Mean 1RM and 70% of 1RM for each bench angle are displayed in Table 1.

Anterior Deltoid

An ANOVA indicated significant differences in the amount of activation within the anterior deltoid between angles ($p < 0.05$; $F(1,12) = 76.795$) (Figure 1). Post hoc analyses revealed significant differences in the amount of activation within the anterior deltoid existed when comparing chest presses performed at 0° above horizontal to 28° above horizontal ($p = 0.002$; ES = 0.19), 0° above horizontal to 44° above horizontal ($p = 0.012$; ES = 0.23), and 0° above horizontal to 56° above horizontal ($p = 0.014$; ES = 0.26). There were no other significant differences in EMG between any of the other angles.

Clavicular Head of the Pectoralis Major

A significant difference in the amount of activation within the clavicular head of the pectoralis major was evident between angles ($p < 0.05$; $F(1,12) = 100.933$) (Figure 2). Follow-up analyses indicated significant differences between 0° above horizontal to 44° above horizontal ($p = 0.010$; ES = 0.31), 0° above horizontal to 56° above horizontal ($p = 0.013$; ES = 0.20), and 28° above horizontal to 44° above horizontal ($p = 0.003$; ES = 0.27). There were no other significant differences in EMG between any of the other angles.

Sternocostal Head of the Pectoralis Major

A significant difference in activation of the sternocostal head of the pectoralis major was demonstrated between angles ($p < 0.05$; $F(1,12) = 43.522$) (Figure 3). Significant differences existed between 0° above horizontal to 28° above horizontal ($p = 0.013$; ES = 0.01), 0° above horizontal to 44° above horizontal ($p = 0.018$; ES = 0.33), 0° above horizontal to 56° above horizontal ($p < 0.001$; ES = 0.75), 28° above horizontal to 56° above horizontal ($p = 0.003$; ES = 0.59), and 44° above horizontal to 56° above horizontal ($v < 0.001$; ES = 0.37). There were no other significant differences in EMG between any of the other angles.

Discussion

In this study, the activation levels of the 2 heads of the pectoralis major and the anterior head of the deltoid were measured while performing a bench press exercise at 4 different angles of incline. For the clavicular head of the pectoralis major, the level of activation was higher when the chest press was performed in an inclined position. In particular, in comparison to the horizontal chest press, the clavicular head of the pectoralis major experienced significantly heightened activity levels at bench angles of 44 and 56°, but not 28°, above horizontal.

The lack of increase in clavicular head activity at the bench angle of 28° is consistent with the results of Barnett et al. (2) along with Glass and Armstrong (9), who both failed to observe an increase in activation of the clavicular head of the pectoralis major when the chest press was performed at an angle of incline of 40 and 30°, respectively. When considered collectively, these findings indicate that a small increase in bench angle (e.g., less than 40°) has minimal influence on the activation of clavicular head.

In contrast to the 28° position, the higher bench angles of 44 and 56° resulted in significantly improved recruitment of the clavicular head. Although clavicular head activity in the 56° position was significantly greater than that produced in the horizontal position, it should be noted that activity in this position was less than the 44° position. Although this difference was not significant, it did approach significance ($p = 0.052$) and lends some support to the suggestion by Graham (10,11), who hypothesized that a bench angle of 45° above horizontal is optimal for activation of the clavicular head when performing the incline chest press. Further, the decrease in activity at the 56° bench angle points toward an inverted U relationship between bench angle and clavicular head recruitment.

Similar to the clavicular head of the pectoralis major, activation of the anterior deltoid was significantly greater at all 3 angles of incline in comparison to when the chest press was performed in the horizontal position. These results confirm the findings of Barnett et al. (2), who also demonstrated anterior deltoid activity during the chest press grew as the angle of bench incline increased.

Exhibiting an almost opposite response to the clavicular head was the pattern of activation of sternocostal head of the pectoralis major. Activation of the sternocostal head was highest in the horizontal chest press position and significantly declined with each increase in bench angle. These results support those of Barnett et al. (2), in which, the horizontal angle was best at recruiting the muscle fibers from the sternocostal region of the pectoralis major.

One of the key factors influencing the degree of activation of a muscle is the force requirements of an action, with greater force requirements demanding greater muscle activation. In the present study, the absolute force requirements (the load lifted) imposed on the acting muscles decreased as the angle of incline increased. Consequently, it is feasible that the decreased activation of the sternocostal head as the bench angle increased may be because of the reduction in load. However, the reduction in the load used at the higher bench angles does not explain the increase in clavicular head and anterior deltoid activity observed at the higher angles. In exercises involving multiple muscles, the degree of activation of any 1 muscle is also influenced by the use or contribution of the other active muscles. The contribution of a muscle will depend on factors such as the specific movement being performed at the joint and the anatomical positioning of the muscle. In the horizontal bench press, the movement being performed at the shoulder is horizontal adduction and the pectoralis major is the primary muscle responsible for this action (13). However, the anatomical positioning of clavicular head of the pectoralis major, not to mention the anterior deltoid, suggests these muscles are more proficient at performing shoulder flexion rather than horizontal adduction (8). Consequently, the contribution of the clavicular head and anterior deltoid during horizontal adduction (as in the horizontal bench press) would have been limited, thus placing greater force demands on the sternocostal head of the pectoralis major. These greater force demands may account for the highest activation levels of the sternocostal head occurring during the flat bench press position. As the angle of the bench increased from the horizontal position, the movement being performed at the shoulder gradually shifted away from horizontal adduction and progressively moved closer to a combination of shoulder flexion and shoulder abduction. The origin and orientation of the fibers of the sternocostal head of the pectoralis major limit the production of force during shoulder flexion. As a result, there would have been a greater need to recruit the clavicular head of pectoralis major and the anterior deltoid, and this may account for the increase in clavicular head and anterior deltoid activity at the higher bench angles. Furthermore, Barnett et al. (2) observed a reduction in triceps brachii activity when the chest press was performed in an inclined position than when in a flat position. A reduction in triceps activity at the higher bench angles would have further increased the demands placed on the clavicular head and anterior deltoid.

A possible limitation to the results of the present study was the use of a Smith machine, rather than free weights, to execute the bench press exercise. With a Smith machine, the path the bar travels during the movement is limited to the vertical plane. As a result, it would seem the balance requirements when performing the bench press exercise on a Smith machine, in comparison to free weights, would be reduced (7). In addition to maintaining balance during a lift, there are a number of other technical factors potentially influencing muscle activation during the bench press. These include the load lifted, grip width, speed of movement, range of motion, and possibly bench angle. To clearly determine the effect of bench angle, these additional factors needed to be controlled. Grip width, lifting speed, and range of motion were all carefully contolled between angles. The load lifted was relative (70%) to maximum strength at each angle and was representative of loads used in training. The use of the Smith machine, in that it restricted the path of the bar to the vertical plane, was used to remove any potential differences in balance requirements between bench angles, therefore confining any differences in muscle activation to bench angle.

In conclusion, and based on the angles investigated, performing the chest press in an inclined position most effectively recruited the anterior deltoid and the clavicular head of pectoralis major. With respect to the clavicular head, a bench angle of 44° seemed ideal. Alternatively, the sternocostal head of the pectoralis major was activated to the greatest extent when the bench position was horizontal. Thus, it would seem that performing both the flat and incline chest press exercises in a training program is necessary to optimize activation and thus gains in the strength and size of the involved musculature.

Practical Applications

For individuals looking to maximize strength gains, findings from the present study indicate that to successfully train the muscles involved in chest press exercises (sternocostal and clavicular heads of the pectoralis major along with the anterior deltoid), more than 1 angle of bench incline needs to be employed. Specifically, performing the bench press exercise at a horizontal bench position and at an inclined position of approximately 44° (and not lower or higher) is necessary to optimally activate the entire chest musculature. The flat or horizontal bench position preferentially targets the sternocostal head (commonly referred to as the lower part of pectoralis major), whereas an inclined position of approximately 44° is required to effectively recruit the clavicular head (commonly referred to as the upper part of pectoralis major) and the anterior deltoid.

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