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Effects of Variations of the Bench Press Exercise on the EMG Activity of Five Shoulder Muscles

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ABSTRACT

This experiment investigated the effects of varying bench inclination and hand spacing on the EMG activity of five muscles acting at the shoulder joint. Six male weight trainers performed presses under four conditions of trunk inclination and two of hand spacing at 80% of their predetermined max. Preamplified surface EMG electrodes were placed over the five muscles in question. The EMG signals during the 2-sec lift indicated some significant effects of trunk inclination and hand spacing. The sternocostal head of the pectoralis major was more active during the press from a horizontal bench than from a decline bench. Also, the clavicular head of the pectoralis major was no more active during the incline bench press than during the horizontal one, but it was less active during the decline bench press. The clavicular head of the pectoralis major was more active with a narrow hand spacing. Anterior deltoid activity tended to increase as trunk inclination increased. The long head of the triceps brachii was more active during the decline and flat bench presses than the other two conditions, and was also more active with a narrow hand spacing. Latissimus dorsi exhibited low activity in all conditions.

Key Words: weight training, electromyography, pectoralis major, deltoid muscle, triceps brachii

Introduction

Weight training, once reserved for the bodybuilder or power lifter, has been an integral component of the elite athlete's strength program for many years. And the inclusion of weight training as part of a general fitness program has become increasingly popular. In many cases, the use of weights attempts to isolate muscles via basic exercises and variations of these exercises.

The bench press may be the most widely used exercise for developing the upper body (7), particularly the chest (20). The flat bench press is seen as an essential exercise for developing both heads of the pectoralis major (13). The different actions of the two heads of the pectoralis major can be shown by flexing the shoulder about 60°; from this initial position, the clavicular head is a shoulder flexor while the sternocostal head is an extensor (9). Based on this information, the incline bench press is believed to primarily develop the clavicular head of the pectoralis major (7). Further, there is some evidence of a marked decrease in the activity of the sternocostal head during the incline press compared to the flat bench press (11).

It is believed that during the decline press the sternocostal head is preferentially activated (7, 11). Some weight trainers claim that the latissimus dorsi is active during the decline press. Based on the perceived differences between variations of the bench press, it has been advised that weight trainers include incline, flat, and decline bench presses in their training program (10).

With respect to variation in hand spacing, it has been noted that a wider grip requires more activity in the pectoralis major muscles while a narrow grip activates the triceps brachii (6, 11, 14). Hand spacing is also thought to affect activities in the pectoralis major (7) and deltoid muscles (14).

The anecdotal accounts of the effectiveness of these exercises, combined with the scarcity of research on the topic, provided the impetus for this study. Previous studies such as those conducted by Basmajian et al. (2) and Cnockaert et al. (5), who examined the behavior of individual muscles within a group (quadriceps group and elbow flexors, respectively), found that the muscles act in unison to achieve a common end and that differences in activity may be due to structural discreteness. With respect to the pectoralis major, the two heads may act in combination during medial rotation and adduction at the shoulder (19), or independently during flexion (clavicular head) and extension (sternocostal head) from the flexed position (15, 19). Rasch et al. (15) stated that the flexion and extension roles of the two heads are largely determined by the initial glenohumeral position, and that both heads of the pectoralis major (clavicular and sternocostal) are active during horizontal flexion.

It was the purpose of this study to examine the EMG activity of 5 muscles acting about the shoulder joint during different conditions of the two-handed barbell press in which both trunk inclination and hand spacing were varied.

Methods

Subjects

Six men with a minimum of 2 yrs weight training experience were recruited for this study. Participation was voluntary and without remuneration. All subjects signed an informed consent document prior to testing. Physical characteristics were as follows:

- Age, 20–27 yrs (*M*, 23.7; *SE*, 1.1)
- Height, 171.5–184.5 cm (*M*, 177.7; *SE*, 1.1)
- Body mass, 77.5–93.0 kg (*M* 84.8; *SE*, 2.7)
- Biacr. diam., 40.5–44.9 cm (*M*, 42.2; *SE*, 0.7)

Biacromial diameters of each subject were measured using a Holtain anthropometer according to the protocol of Weiner and Lourie (18).

Procedure

In the week prior to testing, maximum presses were obtained for each subject under each condition of trunk inclination and hand spacing (Figure 1). The maximum load lifted in the military press was significantly less ($p < 0.05$) than in the bench press when the trunk was horizontal or at a decline. Although there was approximately a 5% difference between the wide and narrow hand spacing conditions in the bench press, similar to the 7% difference previously found (17), the difference was not statistically significant. The mean loads lifted in the present study were about 10% less than in a previous bench press study (17).

The weights used during the experimental trials were 80% of the predetermined maximum in each condition. A common training load used by many recreational lifters (20), it allowed the subjects to perform all the trials required. Four positions of trunk inclination were investigated: flat (horizontal), incline (40° above horizontal), and decline (18° below horizontal). Three benches commonly seen in local gymnasiums were used. For the vertical trunk position the subject sat on the horizontal bench and did a military press.

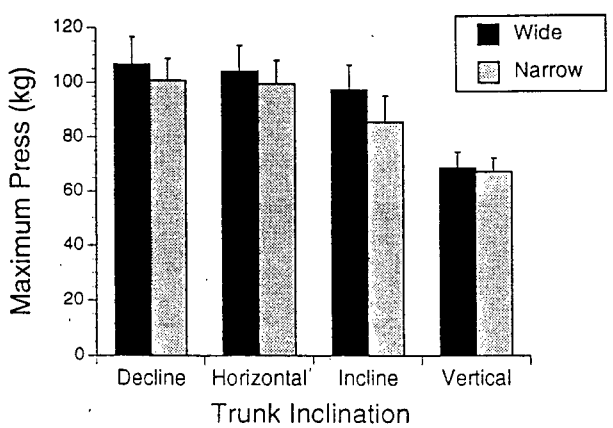

Figure 1. Effects of trunk inclination and hand spacing on maximum weight that could be pressed in each of the 8 conditions.

Two hand spacings on the barbell were used in each condition of trunk inclination. To standardize the narrow and wide hand placements, 100 and 200% of the biacromial diameter, respectively, were used. For all presses, the path of the bar was guided by the vertical poles of a Smith machine. The various starting positions of the barbell were accommodated by placing pegs in appropriate holes drilled at regular intervals in the supports.

Preamplified Qantec electrodes (TPS Electronics Pty Ltd, Springwood, QLD, Australia) were used to record surface EMG from 5 sites: over the bellies of the sternocostal head of the pectoralis major, the clavicular head of the pectoralis major, the anterior deltoid, the long head of the triceps brachii, and the latissimus dorsi (1). In all cases the line between the active electrodes was parallel to the muscle's line of pull. The electrode sites were prepared by shaving, abrasion with emery paper, and swabbing with alcohol to lower skin resistance. Electrode gel was also applied to the preamplified electrodes to increase electrical contact between skin and electrode. Each preamplified electrode assembly was attached to the skin by double-sided adhesive tape and secured by additional adhesive tape.

Each subject did his usual warm-up, then positioned himself on the bench (horizontal, incline, or decline) with the bar resting approximately 15 to 20 mm from the chest, or at the level of C7 for the shoulder (vertical) press. The index fingers of each hand were positioned lateral to the respective markings on the bar (100 or 200% of biacromial diameter) with the forearms pronated. The type of grip used (cylindrical or hook) was self-chosen. Subjects performed the lift in a controlled manner with an appropriate lift time (ascent only) of approximately 2 sec. They had already practiced with a metronome beat and light weight in order to become familiar with the required speed. They were instructed to resist any hyperextension of the vertebral column during the lift. This was visually checked by the experimenters.

Once the subject was ready, the tester began a standard countdown procedure. Two trials under each condition of trunk inclination and hand spacing were recorded; recovery time between trials was controlled by the subject. Recording began approximately 1,000 ms prior to the start of the lift. Completion of the lift, at full elbow extension, was detected visually by the tester. The subjects performed the lifts in random order, thus minimizing any order effect.

Data Analysis

EMG signals were preamplified at the source electrode (× 100) and then conditioned by differential Qantec

amplifiers (TPS Electronics Pty Ltd), which have a common mode rejection ratio of >80dB@50Hz. EMG signals from each trial were low-pass filtered (cutoff at 500 Hz), high-pass filtered (cutoff at 10 Hz), and amplified 10 to 50 times before being sampled at a rate of 1 KHz via the Waveform Analysis Software Program (4) on an IBM compatible microcomputer fitted with a 10-bit A/D board (TPS Electronics Pty Ltd). The digitized EMG signal from each trial was visually checked for noise artifact before being saved on the computer disk. Later the computer software was used to integrate the EMG (IEMG) by true integration of the full-wave rectified signal.

Total lift time was divided into 20 equal integration periods and the IEMG was expressed in total millivolt seconds (mV.s) for the entire concentric phase of the press exercise. The total integral represented total energy in the signal detected by the preamplified electrode on the skin overlying the muscle. Use of the total integral for each trial reduced the effect of speed of lift as a confounding variable. If the lift was slightly faster than required, mean activity would be increased but this would be offset by a shorter lift time. With large differences in lift time it has been shown that slower speeds produce a greater total EMG activity (16), but it is likely that variation in the total integral would be less than the mean integral.

Two-way ANOVAs were used to determine the effects of inclination (4 trunk positions) and hand spacing (2 distances) on the electrical activity of each muscle. Tukey post hoc tests revealed the source of any significant results. The criterion alpha level was set at 0.05 for all statistical analyses.

Results

Sternocostal Head of the Pectoralis Major

IEMG values of the sternocostal head of the pectoralis major for each exercise are described in Figure 2. Significant interactions were found when both inclination and hand spacing were considered. The activities during the press when the trunk was vertical (i.e., vertical press) were significantly less ($p < 0.05$) than at all other inclinations, regardless of hand spacing. With wide hand spacing, the activity during the horizontal position was greater than for both decline and incline positions ($p < 0.05$). With narrow hand spacing, the activity during the incline press was less than for the horizontal press ($p < 0.05$). Generally, hand spacing had no effect on muscle activation except during the incline press when the wide grip elicited greater activity ($p < 0.05$).

Clavicular Head of the Pectoralis Major

Concerning inclination alone, a significant increase ($p < 0.05$) in activity of the clavicular head of the pectoralis major was evident in the transition from decline to incline press (Figure 3). The activity during the press with a vertical trunk was significantly less ($p < 0.05$) than for both the incline and horizontal press conditions. A main effect of hand spacing was also found: the narrow grip (0.474 ± 0.044 mV · s) elicited significantly ($p < 0.01$) greater activity than the wide grip (0.361 ± 0.048 mV · s).

Anterior Deltoid

Significant interactions were found when both inclination and hand spacing were considered (Figure 4). Activity tended to increase as trunk inclination increased, but this was more apparent with wide hand spacing. With narrow hand spacing, activity was greater when the trunk was vertical than during the decline press ($p < 0.05$). With wide hand spacing, pressing with the trunk both vertical and inclined exhibited greater activity than for the horizontal and decline press conditions ($p < 0.05$).

Long Head of Triceps Brachii

There were main effects for both trunk inclination and hand spacing. The activity of the long head of the triceps brachii was significantly less ($p< 0.05$) during

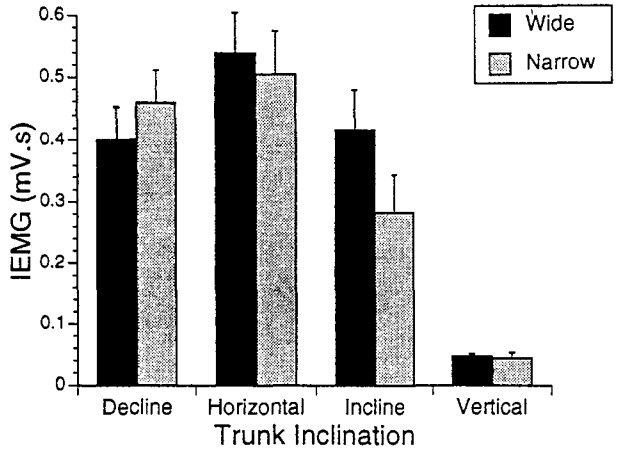

Figure 2. Effects of trunk inclination and hand spacing on the activity of the sternocostal head of the pectoralis major.

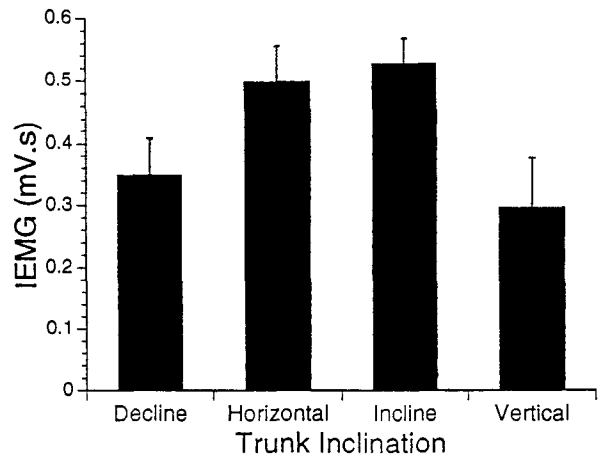

Figure 3. Effects of trunk inclination on the activity of the clavicular head of the pectoralis major.

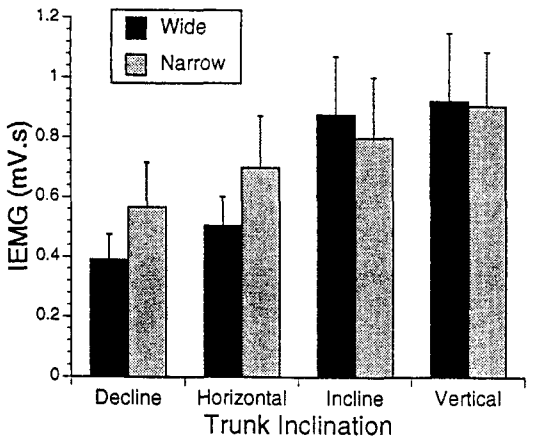

Figure 4. Effects of trunk inclination and hand spacing on the activity of the anterior deltoid.

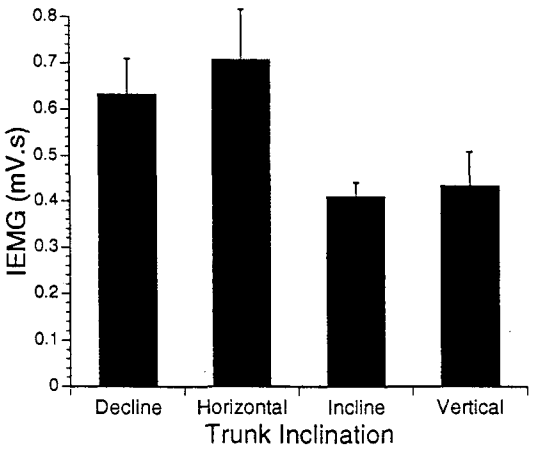

Figure 5. Effects of trunk inclination on the activity of the triceps brachii.

both incline and vertical press conditions than the horizontal condition (Figure 5). A main effect of hand spacing was also observed; the narrow grip (0.609 ± 0.057 mV · s) exhibited significantly greater activity than the wide grip (0.482 ± 0.061 mV · s) ($p < 0.05$).

Latissimus Dorsi

EMG activity of the latissimus dorsi was very low under all conditions, but there was a short burst of activity just prior to the start of the lift. Significant interactions were found when both inclination and hand spacing were considered (Figure 6). For both hand spacings, the low activity of the latissimus dorsi was significantly greater ($p < 0.05$) during the decline press than during the incline press. With a wide grip, the activity during the decline press was greater than during both the vertical and horizontal press, regardless of hand spacing. With a narrow grip, the activity during the decline press was significantly greater ($p < 0.05$) than during the horizontal press.

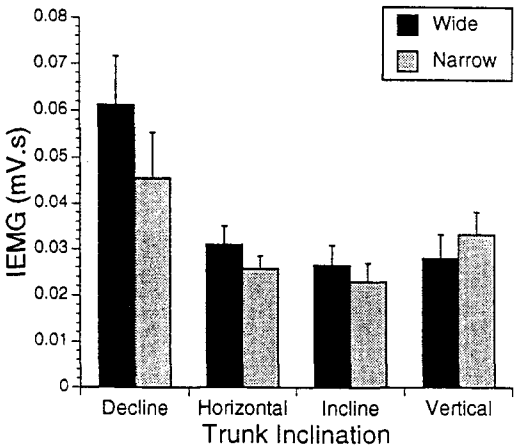

Figure 6. Effects of trunk inclination and hand spacing on the activity of the latissimus dorsi.

Discussion

A press involves a combination of movements in the sagittal (flexion), coronal (abduction/adduction), and transverse (horizontal flexion) planes. Glenohumeral motion during a flat bench press with wide hand spacing is predominantly horizontal flexion; during a vertical press with narrow hand spacing the predominant movement is flexion, if the elbows are held close to the trunk. Wide hand spacing during a vertical press will cause mainly glenohumeral abduction (see Table 1). Different muscles acting on the shoulder joint will be more effective in producing certain components of the total action than others. It is not yet known how much change in body posture or hand spacing is required to produce a measurable effect in muscle activity.

There was a trend for the maximum weight to decrease from the decline press to the vertical press (Figure 1). During each of the four presses, movement occurred within a different arc of the total range of glenohumeral movement. Particularly during the vertical press with narrow hand spacing, the initial and final positions of the glenohumeral joint were more flexed than in the other conditions. Therefore, both the directions of movement and the arc of motion probably affected the total activity of each muscle during each press. The different arcs complicate interpretation of the EMG signals because muscle length affects the size of the EMG signal (8).

Table 1
Actions at the Glenohumeral Joint With a Wide Hand Spacing

Inclination	Abduction	Horiz. flex.	Adduction
Vertical press	X		
Incline press	X	X	
Horizontal press		X	
Decline press		X	X

Main Effects

Trunk Inclination. The significant reduction in activity of the clavicular head of the pectoralis major during the decline press versus the incline press is due to either a reduction in the flexion component at the shoulder joint or a reduced glenohumeral range of motion. Displacement of the bar was greatest for the incline press and least during the decline press. Since the clavicular head of the pectoralis major is involved in movements requiring not only pure flexion but also horizontal flexion and adduction, the activity of this muscle decreased significantly during the transition from both the horizontal and incline presses to the vertical press. This is because the requirements for horizontal flexion and adduction are minimal during the vertical press, when the clavicular head of pectoralis major is least active (Table 2).

Table 2
Effects of Trunk Inclination on EMG Activities

Muscles	Maximum	Minimum
Sternocostal head of pectoralis major	Horizontal*	Vertical
Clavicular head of pectoralis major	Incline	Vertical
Anterior deltoid	Vertical	Decline*
Long head of triceps brachii	Horizontal	Incline

*Wide hand spacing.

Although the clavicular head of the pectoralis major is a flexor of the glenohumeral joint, it is unlikely to maintain this action throughout the range of flexion. As the humerus moves above the horizontal position, the humeral attachment of the clavicular head will be above the clavicle. Thus the clavicular head of the pectoralis major will not be an effective flexor in this phase of the vertical press. This may also explain the lack of expected increase in activity during the transition from flat to incline press. The final phase during the incline press involves flexion past 90°. The suggestion that the clavicular head is well exercised by the flat and incline press (11) is supported by our results, but the press with a decline bench is associated with less activity.

Although bar displacement during the incline press was greater than during the horizontal press, there was a significant decrease in the activity of the long head of the triceps brachii (Table 2). Any interpretation of triceps brachii activity should concentrate on elbow motion, although the activity of the long head may be influenced by shoulder motion because of its attachment to the infraglenoid tubercle. Its actions include glenohumeral adduction and extension whereas the other two heads of the triceps can only produce elbow extension.

Hand Spacing. With a wide hand spacing for the vertical press, the movement is almost pure glenohumeral abduction; for the flat bench press it is mainly horizontal flexion. Under all conditions there is a larger flexion component when the hands are held closer together. This would explain the generally greater activity in the clavicular head of the pectoralis major during all press exercises with a narrow hand spacing.

The sternocostal head of the pectoralis major was largely unaffected by the variation of hand spacing, which is inconsistent with the findings of McLaughlin (12). One explanation may be the position of the elbows during the presses. Although the positions of the hands on the barbell were strictly defined, this was not the case for the elbows. The subjects performed each lift in their own style. The strength of presses with a wide hand spacing tended to be slightly greater, as recently found by Wagner et al. (17), and there could be a tendency for the elbows to move away from the trunk during the press with a narrow hand spacing, thereby increasing horizontal flexion and reducing the flexion component of the movement. The sternocostal head of the pectoralis major may have exhibited differences related to hand spacing if the pattern of movement had been more strictly controlled. Under the experimental conditions, no differences were found for the sternocostal head relative to hand spacing.

The long head of the triceps brachii also exhibited greater activity with a narrow hand spacing, but this was probably due to the ranges of elbow motion being greater with a narrow hand spacing. Therefore the rate of concentric contraction would have been higher, requiring the recruitment of more motor units as the strength of each motor unit decreased (3).

Interactions

In addition to the statistically analyzed interactions between trunk inclination and hand spacing for each muscle, there are the possible interactions between muscles whereby changes in activation, as estimated by IEMG, may reflect changes in the effectiveness of the muscle under varying conditions.

An increase in trunk inclination from the horizontal to the incline press resulted in a significant decrease in the activity of the sternocostal head of the pectoralis major, in agreement with the results of McLaughlin (11). Even at 45 to 60° of glenohumeral flexion, the sternocostal head becomes an extensor (9, 15, 19), and the low level of activity during the vertical press is a good indication of its change of role through the range of flexion (see Table 2). The low level of sternocostal head activity during the vertical press can be contrasted with the high level of activity in the anterior deltoid, which is an abductor and flexor at the glenohumeral joint. Figures 2 and 4 and Table 2 indicate opposite trends for the sternocostal head of the pectoralis major and the anterior deltoid muscle. The incline press required a greater degree of abduction and a concomitant decrease in adduction compared to the decline press.

Vertical inclination of the trunk during the vertical press, with both wide and narrow spacing, elicited

significantly less activity in the sternocostal head of the pectoralis major than was produced during presses in the six other conditions. This may be due to the large degrees of humeral abduction (wide) or flexion (narrow) required during the vertical press (Table 1). The sternocostal head does not play a role in either of these glenohumeral joint movements. Also, the activity of the sternocostal head during the incline press was significantly less with a narrow grip than with a wide grip; during the decline press it was less with either grip.

The requirement for horizontal flexion during the incline press with a narrow grip is greatly reduced whereas those for humeral abduction and flexion are increased (Table 1). The decrease in activity of the sternocostal head during the transition from flat to decline press, both with a wide grip, is likely due mainly to a decreased range of glenohumeral movement. There may also be some minimal contribution to adduction from the latissimus dorsi during the decline press.

The anterior deltoid is not only a flexor of the humerus but also an abductor of it. The trend exhibited by the anterior deltoid as the inclination decreased is due to the reduced degree, or absence, of humeral abduction (see Table 1). The large degree of humeral abduction required during both the incline and vertical presses, regardless of hand spacing, explains the lack of statistical significance between these four conditions (see Figure 4).

The significantly greater activity of the latissimus dorsi during the decline press with a wide grip, versus all other inclinations regardless of hand spacing, may be due to the greater degree of adduction required during this press. The latissimus dorsi is a humeral adductor but it is also an extensor at the glenohumeral joint. This second action would explain its low level of activity during all presses. Although the activity levels varied, and some statistical differences were found, all levels were relatively low whereas for all the other muscles the activity levels were relatively high.

Practical Applications

1. The incline press does not result in greater activation of the clavicular head of the pectoralis major than does the horizontal press.
2. Hand spacing significantly affects the activity of the clavicular head of the pectoralis major and the long head of the triceps brachii, with a narrow spacing yielding the greater response.
3. Employing the decline press to recruit the sternocostal head of the pectoralis major is not justified because the EMG activity obtained from the horizontal press with either hand spacing exceeds that elicited during the decline press.
4. Any benefits of varying the bench inclination for the pectoralis major are more likely due to psychological or biological factors (other than the quantity of EMG activation).
5. Activation of the anterior deltoid muscle tends to increase as trunk inclination increases, thus a military press is most effective for training this muscle.
6. No style of press should be considered an exercise for the latissimus dorsi.

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