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Electromyographical Activity of the Pectoralis Muscle During Incline and Decline Bench Presses

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Reference Data

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ABSTRACT

The purpose of this study was to determine the relationship between motor unit recruitment within two areas of the pectoralis major and two forms of bench press exercise. Fifteen young men experienced in weight lifting completed 6 repetitions of the bench press at incline and decline angles of +30 and −15° from horizontal, respectively. Electrodes were placed over the pectoralis major at the 2nd and 5th intercostal spaces, midclavicular line. Surface electromyography was recorded and integrated during the concentric (Con) and eccentric (Ecc) phases of each repetition. Reliability of IEMG across repetitions was $r = 0.87$. Dependent means t-tests were used to examine motor unit activation for the lower (incline vs. decline) and upper pectoral muscles. Results showed significantly greater lower pectoral Con activation during decline bench press. The same result was seen during the Ecc phase. No significant differences were seen in upper pectoral activation between incline and decline bench press. It is concluded there are variations in the activation of the lower pectoralis major with regard to the angle of bench press, while the upper pectoral portion is unchanged.

Key Words: motor unit recruitment, weight training

Introduction

In multifunctional muscles, motor unit recruitment depends on the task or the direction of exerted force (4, 16, 17, 19, 20, 21). Thus there is a direct relationship between the location of motor units within a muscle and the specific patterns in which they are recruited for work. These recruitment patterns are found in multifunctional muscles of wide origin, such as the pectoralis major (2). The pectoral muscles can be used to perform a combination of movements through numerous anatomical planes.

Specificity of movement patterns is supported by the concept that the direction and mechanical advantage gained in a specific movement will affect which motor units are recruited for a certain task (6, 16). Shelvin et al. (17) found a definite relationship between direction of movement and motor unit recruitment in the pectorals.

This research suggests that the direction of movement involving the use of the pectorals will determine which motor units will be activated to complete a certain task. The current rationale of performing a bench press at different angles is that different areas of the pectoralis major can be isolated and trained more intensely, thus increasing the number and frequency of the motor units recruited. According to strength training theories, this isolation and increased frequency of activation will result in hypertrophy of different areas of the pectoralis major (6).

Recent research has shown that motor unit activation may differ across portions of the pectoralis. Barnett et al. (1) examined the integrated electromyographic (IEMG) activity of the upper (clavicular) and middle (sternal) portion of the pectoralis major during horizontal, incline, and decline bench presses. They found that the clavicular portion of the pectoralis was more active during horizontal than during decline bench press, and the sternal portion was less active during decline bench press than during both horizontal and incline bench.

It is commonly believed that the decline bench press is effective for developing the lower sternal portion of the pectoralis major. However, we know of no studies that have examined the activation of this portion of the pectoralis during bench press exercise. The purpose of this study was to determine the motor unit recruitment patterns of the upper (clavicular) and lower sternal portion of the pectoral muscles during the incline and decline bench press.

Methods

Fifteen college-age men reported to the human performance laboratory on two occasions. Subject characteristics ($M \pm SD$) were as follows:

- Age: 19.54 ± 1.13 yrs
- Height: 183.65 ± 5.62 cm
- Mass: 83.44 ± 6.24 kg
- Body fat: 10.49 ± 5.34%
- Experience: 5.08 ± 1.5 yrs
- Heart rate: 67.85 ± 7.89 bpm
- Resting systolic BP: 125.23 ± 7.89 mmHg
- Resting diastolic BP: 76.00 ± 10.26 mmHg.

All subjects had to have at least 1 year of weight lifting experience prior to the study and the ability to bench press at least 100% of their body weight once. These criteria were established in order to recruit subjects who could successfully complete the exercises according to predetermined testing guidelines. This also meant the subjects were familiar with the exercises involved.

Testing Procedure

Testing sessions included a 1-RM measurement of incline and decline bench press strength, along with anthropometric measurements, and electromyographic (EMG) analysis of motor unit recruitment during submaximal incline and decline bench press exercise.

On Test Day 1, all subjects read and signed an informed consent document and completed a physical activity and health history questionnaire. Resting heart rate was recorded by palpating the radial artery for 10 sec with the subject seated. Resting blood pressure was taken by auscultation of the brachial artery (5th Korotkoff sound) using a standard sphygmomanometer and stethoscope. Height (cm) was measured with a stadiometer and weight (kg) was measured with a Health-o-Meter scale. Skinfold body fat % was determined via the 7-site measuring method: chest, midaxillary, triceps, subscapular, suprailliac, abdominal, and thigh. Body density was estimated using the equations of Jackson and Pollock (10), and body fat was calculated using the Siri equation (18).

The last testing procedure on Day 1 was the completion of a 1-RM incline and decline bench press with the trunk +30 and –15° from horizontal, respectively. These bench angles were measured using an international standard goniometer. All subjects completed a 10-min warm-up followed at random by either an incline or decline bench press 1-RM test. Test order was counterbalanced and a 5-min rest interval was allowed between each attempt. The weight was increased in increments of 5–20 lbs depending on the subject's capability. A 10-min rest period was allowed between the incline and decline 1-RM tests. A spotter was present during each lift to prevent the subject from being injured.

At least 48 hours later, all subjects performed submaximal incline and decline bench presses while the IEMG activity of the upper and lower sternal pectoral muscle was being measured. These exercises were counterbalanced to reduce any order or fatigue effect. The incline bench press test included a warm-up set of 10 reps at 40% of 1-RM. Bench angle was set at +30° from horizontal. A 5-min rest interval was given between the warm-up and submaximal test.

The submaximal test consisted of 1 set of 6 reps with 70% of 1-RM with the simultaneous measurement of EMG activity. This intensity was chosen because it is a typical training intensity used to induce muscular hypertrophy while being light enough to ensure that the subjects could easily complete the required lifts. Research has shown that the IEMG signal will continue to increase with fatiguing contractions (2), making a stable measurement of the integrated signal problematic. We sought to avoid this problem by choosing a load that was similar to typical training, yet we did not allow the subjects to lift to fatigue.

The time taken to complete each lift was restricted to 3 sec per lift (1.5-sec concentric and 1.5-sec eccentric contraction), as counted by a metronome. The warm-up set was also completed at the same pace to increase the subject's familiarity with the timing. A spotter was present to keep the subject from getting injured. The decline bench press was identical to those described for the incline press except that it was performed at a bench angle of –15° from horizontal.

EMG Recording

Prior to the submaximal lifts, the skin was prepared for surface electrode placement by shaving a predetermined area in order to remove all hair and dead skin. The area was then abraded with a course pad and rubbed clean with a cloth saturated in isopropyl alcohol. This process was continued until a skin impedance less than 10,000 ohms was achieved (2, 5). Skin impedance was measured using a standard voltmeter. Twelve of the 15 subjects had a skin impedance value less than 5,000 ohms.

EMG activity was recorded using bipolar surface electrodes 12 mm in diameter with an interelectrode distance of 2.5 cm. Surface electrodes were placed on two sites on the pectoralis major using anatomical landmarks. For the upper pectoralis, the electrodes were attached at the 2nd intercostal space of the rib cage along the midclavicular line. The electrodes were placed on the lower sternal pectoralis at the 5th intercostal space along the same midclavicular line. Two ground surface electrodes were placed on bony prominences of the styloid and olecranon processes. Raw EMG data (sample rate = 1,024 Hz) were overlaid during the test with markers set by a technician that identified the concentric and eccentric phases of contraction. The signal was filtered initially by a remote pack (TEL 100M, BIOPAC Systems) attached to the subject and was amplified and transmitted to a high-speed data acquisition system (MP100, BIOPAC) interfaced with a 486 microcomputer.

Following raw data acquisition, EMG analysis software was used to remove ECG and motion artifact. A high-pass filter with a cutoff frequency of 30 Hz using 255 coefficients (Blackman –67dB) was employed as suggested by the manufacturer to remove ECG artifact (Acqknowledge Software, Mirosoft Corp.). Total sample length was approximately 25 sec, with time allowed prior to exercise to ensure accurate data sampling. Following data collection the samples were stored and later filtered, rectified, and integrated using postanalysis software. The final IEMG values for each concentric and eccentric contraction were averaged across 6 reps and recorded.

IEMG Reliability Testing

Prior to the present investigation, 10 college-age men, separate from the study subjects, were tested in order to compute reliability for the EMG testing methods and determine whether a single set of lifts was representative of additional sets. They performed the incline bench press only, at an angle of +30° from horizontal. Each performed a warm-up set of 10 reps at 40% of his self-reported 1-RM. A 5-min rest interval was allowed between sets, after which each subject completed two 6-rep sets at 70% of his self-reported 1-RM load. EMG assessment and skin preparation were identical to the procedures used in the present investigation. Skin impedance was measured to ensure that the values were less than 10,000 ohms.

Mean, standard deviation, and coefficient of variation were determined using the recorded IEMG samples to evaluate interset and intraset reliability. The final IEMG values were standardized to a common sample number. The values produced from the 6-rep sets were then averaged. Mean reliability across 6 reps expressed by the coefficient of variation was 16.22 (range = 7.0 to 22.0) with a set-to-set reliability of 0.87. These results are comparable to past research examining the reliability of surface EMG measurements (7, 11–13).

Statistical Analysis

Differences between the incline and decline 1-RM bench press were examined for lower and upper pectoral overall activation using dependent means *t*-tests. Analysis was performed separately for concentric and eccentric phases of the lifts. Significance was set at $p < 0.05$.

Results

Mean weight lifting experience for all subjects was 5.08 ± 1.5 yrs. Average subject strength-to-body-weight ratios for incline and decline press were 1.07 and 1.25, respectively. According to Heyward (9), the average strength-to-body-weight ratio for bench press is 1.00 for college-age men. Thus the subjects in the present study were stronger than average. Figure 1 shows the absolute values for incline and decline bench press 1-RM. Decline 1-RM was significantly greater than incline 1-RM bench press.

Figures 2 and 3 present a typical subject's raw EMG data during an incline and decline bench press. The EMG activation of the upper pectoral is displayed at the top of each figure. Due to the location of the EMG electrodes, significant ECG signal artifact was seen in the sample prior to filtering. We were able to virtually eliminate all ECG artifact as well as low frequency oscillations from the lifting motion.

Figure 4 presents IEMG data from the lower sternal pectoral muscles during the incline and decline bench press. The decline bench press elicited a significantly higher overall EMG activation for both concentric and eccentric contractions compared to the incline bench press ($p = 0.003$). Figure 5 presents similar IEMG comparisons for the upper (clavicular) portion of the pectoralis muscles. There was no significant difference in activation of the upper pectoral portion during either the incline or decline bench press ($p = 0.06$).

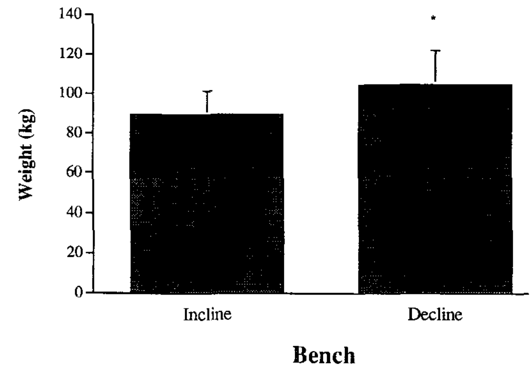

Figure 1. Comparison between incline and decline bench press 1-RM. *Significant difference between both lifting techniques, $p < 0.05$.

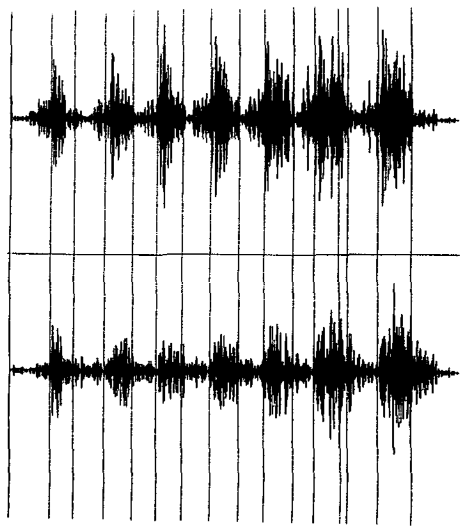

Figure 2. Raw EMG data during submaximal incline bench press. Top: the upper (clavicular) pectoralis. Bottom: lower sternal activation.

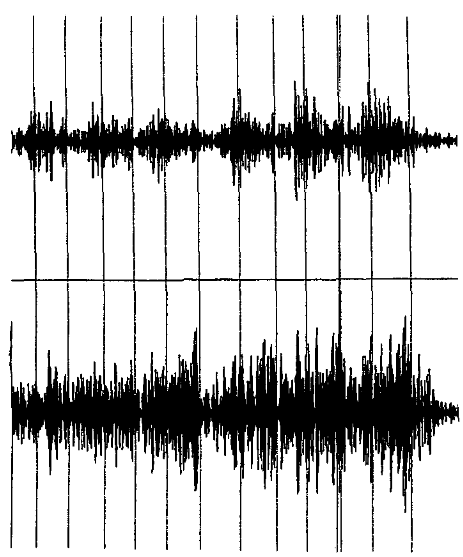

Figure 3. Raw EMG data during submaximal decline bench press. Top: the upper (clavicular) pectoralis. Bottom: lower sternal activation.

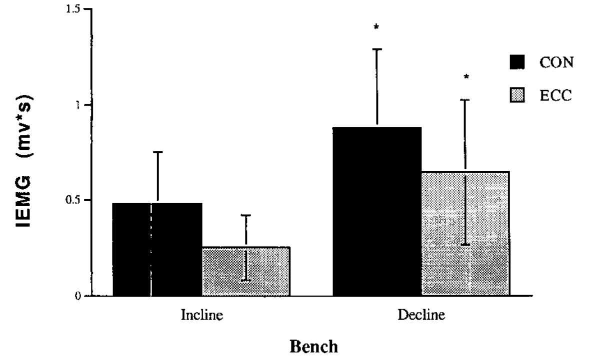

Figure 4. IEMG data for lower sternal portion of pectoral muscles during incline and decline bench press. Data presented for both concentric (Con) and eccentric (Ecc) exercise. *Signif. diff. in activation between incline and decline bench press.

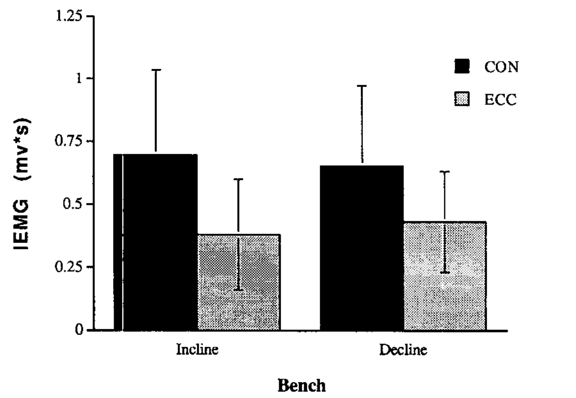

Figure 5. IEMG data for the upper (clavicular) portion of pectoral muscles during incline and decline bench press. Data presented for both concentric (Con) and eccentric (Ecc) exercise.

Discussion

Electromyography has been proven effective in assessing the motor unit recruitment patterns of muscles (1–3, 5, 8). Integrated EMG activity is linearly related to force output as well as oxygen consumption (3, 14, 15). The present study demonstrates that the motor units of the upper region of the pectoralis major were activated equally during both the incline and decline bench press. Conversely, the lower sternal portion of the pectoralis did show a specificity of recruitment, being recruited to a significantly greater extent during decline than during incline bench press.

In multifunctional muscles of wide origin such as the pectoralis major, the order of motor unit recruitment may depend on the task or on the direction of exerted force through its effect on mechanical advantage (2, 4, 6, 16, 17, 19–21). Our data show that performing the bench press in a decline position leads to recruitment of a greater portion of the pectoralis muscle. There is evidence that independent synaptic input for different motor units is contained in one muscle. Ter Haar Romeny et al. (20) investigated the motor unit recruitment patterns of the biceps muscle during flexion, supination, and exorotation. Their results revealed a threshold for motor unit activation, and some motor units were specifically recruited during single movements (flexion). As the amount of applied force was increased, more motor units were recruited.

The intensity of exercise in the present study was 70% of 1-RM. It is plausible that the decline position led to recruitment of more motor units in the lower sternal pectoralis muscles. This advantage may even contribute to force generation at higher loads. The subjects' 1-RM on the decline bench press was 14.5% higher than on the incline bench press (Figure 1). This suggests that the decline bench press is better at engaging the greatest amount of muscle mass in the pectorals.

This is supported by the higher overall activation of both aspects of the pectoralis during eccentric exercise, with a trend toward the same effect during concentric exercise. However, our results are specific to the submaximal loading phase of the bench press and not the final fatigue phase. As the muscle fatigues, motor unit recruitment increases in the exercising muscle (2), so we do not know what the recruitment pattern looks like under maximal fatigue conditions. Thus it is possible that at fatigue all aspects of the pectoral muscles are activated. However, the fact that decline 1-RM is significantly higher than during the incline bench press suggests that either accessory muscles are used during a maximal decline bench, or a larger pectoral region is activated.

Mechanical advantage can also be altered by changing the width of the subject's grip on the bar. Barnett et al. (1) found that a wide hand grip induced significantly more activation in the middle portion (sternalcostal) of the pectoralis during flat bench press than did a narrow grip. Interestingly, they found that the greatest activation of the clavicular portion of the pectoralis was during the flat and incline bench presses, while there was a significantly lower activation during the decline bench press. In the present study, the clavicular portion of the pectoralis was activated to a similar extent during both the incline and decline bench press.

A common problem in EMG research is that there may be variation in the magnitude of the EMG signal as a result of electrode placement. In the present study, we placed the electrodes using anatomical landmarks and at basically opposite ends of the pectoralis. This helped to reduce "cross talk" from other portions of the pectoralis, which may have obscured differences in motor unit recruitment patterns. The electrode positioning in the study by Barnnet et al. differed from that in the present study. Our electrode placement for the lower sternal portion of the pectoralis was lower than theirs and may explain the different results during decline bench press. In addition, the inclination used in the present study (+30°) as well as the declination (–15°) was not as dramatic as in the study by Barnett et al. (+40° and −18°). These differences add credence to the suggestion that motor unit recruitment is task- and position-specific.

The results of this research support the use of the decline bench press for maximizing motor unit recruitment of the lower sternal portion of the pectoralis major during submaximal weight lifting. The incline bench press appears to work well for stimulating motor unit recruitment in the upper pectoral, but not the lower pectoral.

Practical Applications

Persons interested in strength training should use exercises involving the most motor units within a given muscle. It appears that the portion of the pectoral muscle recruited during the bench press is dependent on the direction relative to the trunk in which the muscle must pull the humerus. Our results show that the submaximal phases of the decline bench press involve a greater overall activation of the pectoral muscles than during the incline bench press. The 1-RM bench press values are highest in the decline position while motor unit recruitment of the upper (clavicular) portion of the pectoralis is similar during the incline and decline bench presses, and the lower sternal portion is significantly more activated during the decline bench press.

Individuals who undergo strength training often use a variety of weight lifting methods such as grip width and lifting angle in an attempt to activate different portions of multifunctional muscles. Our results show that during moderate intensity, nonfatiguing bench press exercise, there is a specificity of motor unit recruitment. That is, the decline bench press induces a greater overall activation of the pectoral muscles as compared to the incline bench press. Further research should focus on the alterations in these recruitment patterns during the fatigue phase of the incline and decline bench presses as well as the patterns during variations of other exercises in both the fatigued and nonfatigued states.

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