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Effects of Horizontal and Incline Bench Press on Neuromuscular Adaptations in Untrained Young Men

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ABSTRACT

International Journal of Exercise Science 13(6): 859-872, 2020. The aim of the current study was to investigate the effects of horizontal and incline bench press as well as the combination of both exercises on neuromuscular adaptation in untrained young men. Forty-seven untrained men were randomly assigned to one of the three groups: 1) a horizontal bench press group (n= 15), 2) an incline bench press group (n= 15), and 3) a combination (horizontal + incline) group (n= 17). Training was conducted once a week for eight weeks, with equalized number of sets among groups. Muscle thickness, isometric strength and electromyography (EMG) amplitude of the pectoralis major were measured one week before and after the training period. There was no difference between groups for the change in horizontal bench press isometric strength (~ 10 kg increase, p=0.776) or incline bench press isometric strength (~ 11 kg increase, p=0.333). Changes in muscle thickness differed only in one of the three sites. The changes in the second intercostal space of the pectoralis major was greatest in the incline pressure group compared with the horizontal [mean difference (95% CI) of 0.62 (0.23, 1.0) cm, p=0.003] and combination groups [mean difference (95% CI) of 0.50 (0.14, 0.86) cm, p=0.008]. The change in EMG amplitude following training differed between groups in only one out of the four sites. The present results indicate that strength and conditioning professionals might consider that horizontal and incline bench press exercises, or a combination of both exercises can render similar change in general strength.

KEY WORDS: Exercise choice, exercise variation, strength, hypertrophy

INTRODUCTION

When designing resistance training programs, strength and conditioning professionals have to take into consideration the manipulation and combination of several training variables, including volume, load, rest intervals, contraction velocity, muscle action, training frequency, and exercise choice and order (2,30). There are many ways to select and vary resistance exercise programs, such as: 1) free weights vs. machine, 2) unilateral vs. bilateral, 3) single- vs. multiple-joint, 4) stable vs. unstable surface, 5) open vs. closed kinetic chain, and 6) flat vs. incline (2). Several studies have been conducted in order to evaluate the effects of exercise choice on neuromuscular adaptations to resistance training (12–14). However, there is a paucity of studies comparing the chronic adaptations to resistance training when the same exercise is performed at different angles (e.g., supine or incline position).

Bench press is a multi-joint exercise that allows large loads to be lifted and that demands high neuromuscular activity, which makes it a popular upper-body exercise utilized to increase muscle size and strength across several populations (31,33). Variation to the bench press exercise may be added by changing the angle of the bench. Bench pressing at different angles elicits differences in muscle activation, force production, etc. that might ultimately impact neuromuscular adaptation. To illustrate, during inclined bench press, the humerus is flexed while it performs horizontal adduction, which involves the recruitment of additional muscles (i.e., infraspinatus, subscapularis, and teres minor) in order to minimize the glenohumeral compression (16). Consequently, the exercise load tends to be reduced as the angle of the bench is increased (33). Upper body surface electromyography (EMG) amplitude may also be affected by changes in the incline angle. Flat bench press produces the highest EMG signal with respect to the sternocostal head of the pectoralis major (4,33), while inclining the bench to 44 degree tends to produce the greatest EMG amplitude within the clavicular portion (33).

Given the impact of joint specificity and the differential loading and EMG amplitudes associated with horizontal and incline bench press exercise (21,29,35), the general recommendation has been to perform both exercises in order to maximize the training stimulus as it relates to muscle growth and strength gains (33). A previous study has suggested that varying resistance exercises for the same muscle group might lead to greater strength gains in comparison to constant exercise (7). The authors evaluated only lower body resistance exercises (i.e., squat, leg press, dead lift and lunge) for the lower limbs. Nonetheless, studies exploring upper body resistance exercises, and the long-term neuromuscular adaptations of the same exercise performed at different angles (e.g., bench press) are lacking. Therefore, there is a critical need to investigate the chronic neuromuscular adaptations to different bench press training protocols (31). Investigating this issue could provide valuable information for strength and conditioning professionals who seek to utilize the most effect resistance training programs.

Therefore, the aim of the current study was to investigate the effects of horizontal and incline bench press as well as the combination of both exercises on neuromuscular adaptation in untrained young men. For the above reasons, it was hypothesized that the combination of both horizontal and incline bench press would maximize neuromuscular adaptations. Additionally, based on the specificity principle, it was expected that there would be angle specific differences between the horizontal and incline bench press.

METHODS

Participants

Seventy-two young male college students were included in the current study. However, data from 16 subjects were excluded because they failed to attend at least 80% of the training sessions (10) and from 2 other subjects because they altered their nutritional habits. Moreover, 7 subjects did not complete the training period for personal reasons. Therefore, a total of 47 subjects (21.1±3.3 years, 71.9±13.5 kg, 176±7 cm) completed the training protocols. The inclusion criteria were: 1) male subjects between the ages of 18 to 30 years; 2) fit for the study by answering no to all PAR-Q questions (32); 3) subjects were involved with moderate physical activity for an average of 3 days a week; and 4) subjects were not engaged in resistance exercise over the past 6 months. Volunteers were told about the design and experimental procedures of the study and all potential risks and discomforts before signing an informed consent form. This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (27) and was approved by the University's Institutional Review Board (Protocol: 44608115.6.0000.558).

Protocol

Figure 1 shows the experimental design of the study. During the first 2-week period, subjects were requested to attend the laboratory on four separate occasions, with a period of at least 48 h between them. The first visit consisted of familiarization to the study procedures and anthropometric assessment (weight and height). Baseline values were assessed in the second occasion in this order: muscle thickness of the pectoralis major, maximal isometric strength and EMG amplitude. In order to better determine the training load, the third visit consisted of the 10-repetition maximum (RM) test for the horizontal and incline bench press, and the 10RM retest was conducted once more in the fourth visit. Thereafter, subjects were randomly assigned to one of the three groups: 1) a horizontal bench press group (n=15), in which subjects were trained using only the horizontal bench press exercise; 2) an incline bench press group (n=15), in which subjects were trained using only the incline bench press exercise; and 3) a combination group (n=17), in which subjects were training utilizing both horizontal and incline bench press exercises. Training was conducted once a week for eight weeks. Subjects in the horizontal and incline bench press groups performed 4 to 6 sets of their specific resistance exercises, while the combination (horizontal + incline) group completed 2 to 3 sets of each exercise. The goal repetitions for each group ranged from 8 to 12RM. If participants were able to complete more repetitions, they were allowed to until task failure was reached.

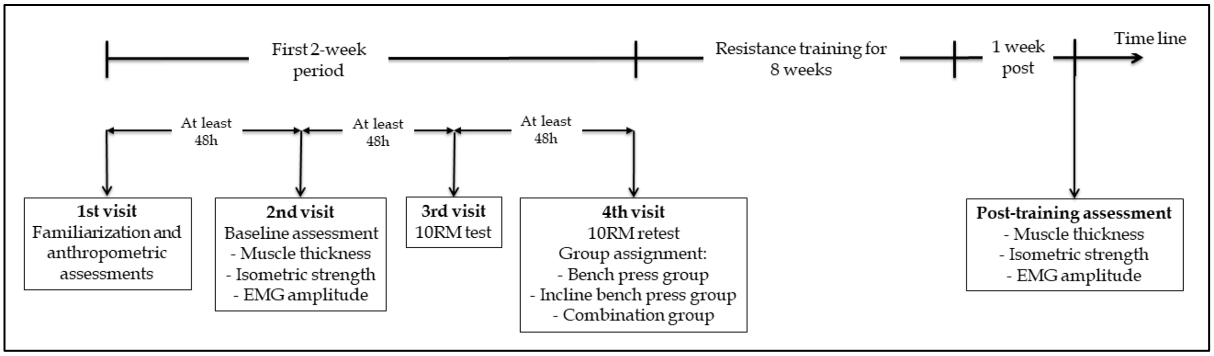

Figure 1. Experimental design of the study.

Muscle thickness of the pectoralis major, maximal isometric strength in the horizontal and incline bench press exercises and surface EMG amplitude were measured, in that order, one week before and after the training period. Forty-seven subjects completed the training protocols, but we had 30 subjects for the muscle thickness data (10 subjects in each group), and 43 subjects for EMG amplitude (13 in the horizontal bench press group, 14 in the incline bench press group and 16 in the combination group). In addition, subjects were advised to visit the laboratory always at the same time of day (± 1 h) and not to alter their nutritional habits (i.e., restricting caloric intake, or becoming a vegetarian).

Muscle thickness: Subjects rested for 10 min on a stretcher in a supine position. Thereafter, a B-Mode ultrasound (model DP- 30; Mindray, Shenzhen, China) was used to assess muscle thickness of the pectoralis major at three different sites: 1) between the second and third costa (second intercostal space), 2) between the third and fourth of costa (third intercostal space), and 3) between the fifth and sixth costa (fifth intercostal space); all under the clavicle midpoint. The measurement points were based on previous studies (28,36). Water-soluble transmission gel was applied to each measurement site, and a 7.5-MHz ultrasound probe was placed perpendicular to the skin, without depressing it. Once the interfaces of the pectoralis major-intercostal muscles and the subcutaneous adipose tissue–pectoralis major muscle were identified, the image was frozen on the monitor and transferred to a flash drive. Then, the Image-J software (version 1.37; National Institute of Health, Bethesda, MD) was used to analyze the images. Pectoralis major muscle thickness was defined as the distance from the subcutaneous adipose tissue-pectoralis major muscle interface to the pectoralis major-intercostal muscles interface.

Maximum isometric strength assessment: Maximum isometric strength in the horizontal and incline bench press exercises was assessed using a load cell (capacity of 500 kgf, EMG System, São José dos Campos, Brazil) connected to a signal acquisition system (SAS1000V4, EMG System). The load cell was calibrated to the signal acquisition system, and data was collected using a sampling rate of 2,000 Hz. The subjects warmed-up by performing 10 repetitions of push-ups before bench press isometric tests. Two minutes later, they performed the horizontal and then, the incline bench press isometric tests. Both tests were performed with the elbow joint positioned at 90° (0° extended) by using a digital goniometer (SAS1000V4, EMG System) connected to a signal acquisition system (SAS1000V4, EMG System). In addition, the incline bench press test was performed at an angle 44 degrees above horizontal (33). Hand position and height of the Smith machine bar were recorded in all exercises to ensure the same positioning for all tests. The subjects were asked to perform 2 maximum voluntary isometric contractions of each exercise for 4 s, with a 60 s rest period between trials. They were also asked to maximally contract their muscles for each isometric test and to maintain their feet on the floor during each test. The signal acquisition system was used to filter the signal, allowing the passage of the low frequencies, with a cutoff frequency of 23 Hz. The highest maximum isometric strength of each attempt was recorded, and the mean peak value used for statistical analysis. Verbal encouragement was given throughout the tests.

Electromyographic activity: Surface EMG amplitude was obtained using active bipolar electrodes (Ag/AgCl – 15 mm diameter with interelectrode distance of 20 mm) and an acquisition system SAS1000V4 (EMG System, Brazil) with gain of 2,000 V/V and common rejection mode of 110 dB). The signal was registered at a frequency of 2,000 and amplified 100 times. Data from the maximal isometric strength tests were synchronized with EMG by the system interface. The electrodes were placed at the: a) sternal head of pectoralis major – at the fifth intercostal space of the rib cage along the midclavicular line (15) and b) the clavicular head of the pectoralis major – at the second intercostal space along the midclavicular line (15). Before electrode fixation, the skin was shaved and cleaned with alcohol according to SENIAM recommendations (17). EMG data were processed in Matlab 6.5 (Mathworks Inc., Natick, MA, USA). The signal was initially band-pass filtered with cutoff frequencies of 20–500 Hz using a fourth order, zero-lag Butterworth filter (1). Then, the root mean square (RMS) was calculated as amplitude indicator in a rectangular window of 4,000 samples (2 s) extracted from the middle part of EMG burst in which the greatest signal energy was identified. The RMS of each attempt was recorded, and the mean RMS value used for statistical analysis.

Resistance training protocol: All subjects trained one day per week for eight weeks as this has previously been show to produce favorable changes at the muscle (9,11). The horizontal bench press group training regimen consisted of horizontal bench press-only, while the incline bench press group performed the incline bench press-only. The combination group performed the horizontal bench press and then, the incline bench press. Additionally, 4-6 sets of seated row and squat or 45° leg press exercises were performed by all subjects. During each training session, the subjects initially warmed-up by performing 10 push-ups. Then, subjects of both the horizontal and incline bench press groups performed 4 sets of 8–12RM of the group designated bench press exercise, whereas the combination group carried out 2 sets of 8–12RM repetitions of both exercises. The load used in each exercise in the first training session was determined by the 10RM test (6). Training volume increased to 6 sets from the fifth week for the horizontal and incline bench press groups, and to 3 sets of both exercises for the combination group. Each repetition lasted 2 s for the concentric and 2 s for the eccentric phase, controlled by an electronic metronome, and the rest interval between sets and exercises were 90 s. Range of motion was also controlled for all groups so that for the eccentric phase, they had to touch their chest and return to a position with their elbows fully extended at the end of the concentric phase. Subjects were instructed to perform all sets until concentric failure, and loads were adjusted during each set by the researcher to maintain the 8–12RM. Although the goal was 8-12RM, subjects were not stopped if they were able to perform more than 12 repetitions. All bench press exercise was completed on a Smith Machine. The incline bench press exercise was performed at 44 degrees above horizontal (33). The subjects were asked to maintain their feet on the floor during bench press exercises. Hands and height of the Smith machine bar was recorded in each exercise to ensure the same positioning in all training sessions.

Statistical Analysis

Changes in muscle size, strength, and surface EMG amplitude were analyzed using an Analysis of Covariance (ANCOVA), with the baseline value as the co-variate. A p value of 0.05 and below was considered statistically significant. All statistical analysis was performed using IBM SPSS 25. Descriptive data are presented as mean (Standard Deviation) and all inferential results are presented as the adjusted change score and 95% confidence interval of that change.

RESULTS

The physical characteristics of the subjects are found in Table 1.

Table 1. Physical characteristics of the participants in the horizontal bench press group, incline bench press group, and the combination group.

	Age (years)	Body Mass (kg)	Height (cm)
Horizontal Bench Group (n=15)	20 (3)	72.8 (16)	179 (5)
Incline Bench Group (n=15)	21 (3)	70.1 (9.3)	175 (9)
Combination Group (n=17)	21 (3)	69.9 (10)	175 (6)

Mean (Standard Deviation).

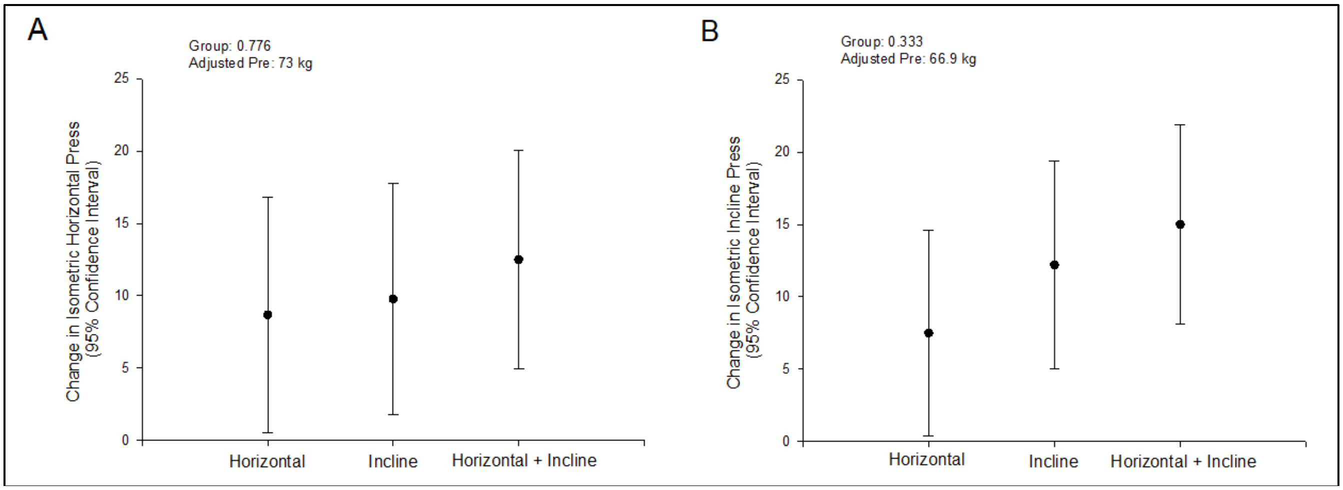

Figure 2. The pre to post change in isometric horizontal (A) and incline (B) bench press across the three separate training groups. Each value reported was adjusted for the baseline value with the middle dot representing the change with the variability represented by 95% confidence intervals.

Changes in maximal isometric strength are reported in Figure 2 (Pre and Post values noted in Table 2). There was no difference between groups for the change in horizontal bench press isometric strength (Figure 2A, p=0.776) or incline bench press isometric strength (Figure 2B, p

= 0.333). This indicated that there were no differences between groups for changes in isometric strength. In an attempt to quantify changes in a more specific task, we compared (post hoc) the change in load lifted for the first set on the first training session to the load lifted for the first set on the final training session. There was no difference (Figure 3A, p=0.264) between groups for the change in load lifted for the horizontal bench press exercise (i.e. horizontal bench press group vs. combination group) but there was a difference between groups for the incline bench press exercise (Figure 3B, p=0.001). The change in load lifted for the incline bench press group was greater than the change in load lifted for the combination group [mean difference (95% CI) of 4.6 (1.9, 7.2) kg].

Table 2. Maximal isometric strength (kgf) over time for each group.

	Pre-training	Post-training
Horizontal press		
Horizontal bench group	72.9 (20.1)	81.6 (18.2)
Incline bench group	74.4 (19.9)	83.6 (19.1)
Combination group	72.1 (22.5)	84.9 (18.9)
Incline press		
Horizontal bench group	68.3 (21.5)	75.3 (18.6)
Incline bench group	66.4 (10.5)	78.8 (16.6)
Combination group	66.2 (21.3)	81.4 (16.0)

Mean (Standard Deviation).

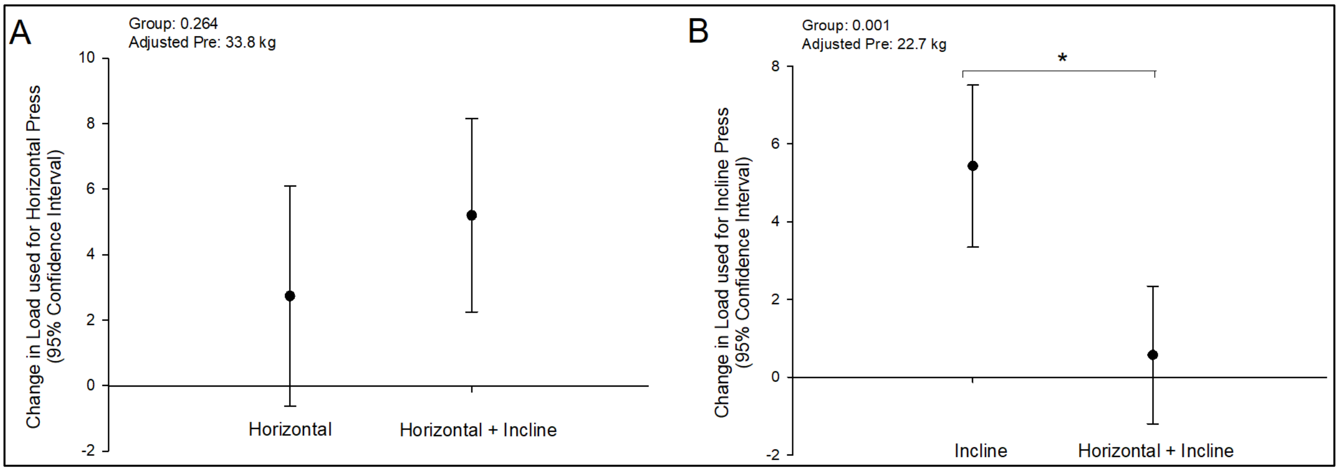

Figure 3. The pre to post change in load lifted for the horizontal (A) and incline (B) bench press. Each value reported was adjusted for the baseline value with the middle dot representing the change with the variability represented by 95% confidence intervals. * represents a significant between group difference in the change in load lifted.

Changes in muscle thickness are reported in Figure 4 (Pre and Post values noted in Table 3). There was a statistical difference for muscle thickness changes in the second intercostal space of the pectoralis major (Figure 4A, p=0.005). The change was greatest in the group training exclusively with the incline bench press compared with the group training exclusively with the horizontal bench press [mean difference (95% CI) of 0.62 (0.23, 1.0) cm, p=0.003] or a combination of the two [mean difference (95% CI) of 0.50 (0.14, 0.86) cm, p=0.008]. There was no difference at this site between the group training exclusively with the horizontal bench press and the group training with a combination [mean difference of 0.11 (-0.25, 0.48) cm, p=0.524]. There was no difference between groups for muscle thickness changes in the third (Figure 4B, p=0.095) or fifth (Figure 4C, p=0.227) intercostal space of the pectoralis major. This indicated that in two of the three sites, changes in muscle thickness were similar.

Table 3. Pectoralis major muscle thickness (mm) over time for each group.

	Pre-training	Post-training
2nd intercostal space		
Horizontal bench group	11.9 (2.0)	15.7 (3.9)
Incline bench group	15.1 (3.8)	24.5 (4.1)
Combination group	14.3 (5.3	18.8 (6.5)
3rd intercostal space		
Horizontal bench group	13.2 (3.5)	19.3 (5.0)
Incline bench group	15.4 (4.3)	23.8 (5.7)
Combination group	17.1 (5.0)	21.2 (4.9)
5th intercostal space		
Horizontal bench group	12.6 (2.7)	18.0 (5.1)
Incline bench group	14.4 (4.2)	22.8 (5.4)
Combination group	16.0 (5.5)	22.7 (5.9)

Mean (Standard Deviation).

Changes in surface EMG amplitude are reported in Figure 5 (Pre and Post values noted in Table 4). There was no statistical difference for changes in surface EMG amplitude in the clavicular region taken during the horizontal bench press (Figure 5A, p=0.516). There was, however, a statistical difference between groups for changes in surface EMG in the sternal region taken during the horizontal bench press (Figure 5C, p=0.012). The change in the group training exclusively with the horizontal bench press was greater than the group training exclusively with the incline bench press [mean difference (95% CI) of 67.6 (8.0, 127.1) µv, p=0.027] or the combination group [mean difference (95%) of 89.1 (30.3, 147.9) µv, p=0.004]. Notably, there was no difference between the incline bench press group and the combination group [mean difference of 21.5 (-34.1, 77.3) µv, p=0.439]. Changes in surface EMG taken during the incline bench did not differ between groups for the clavicular (Figure 5B, p=0.453) region or the sternal region (Figure 5D, p=0.929). This indicated that the change in surface EMG amplitude following training did not differ at 3 out of the 4 sites measured.

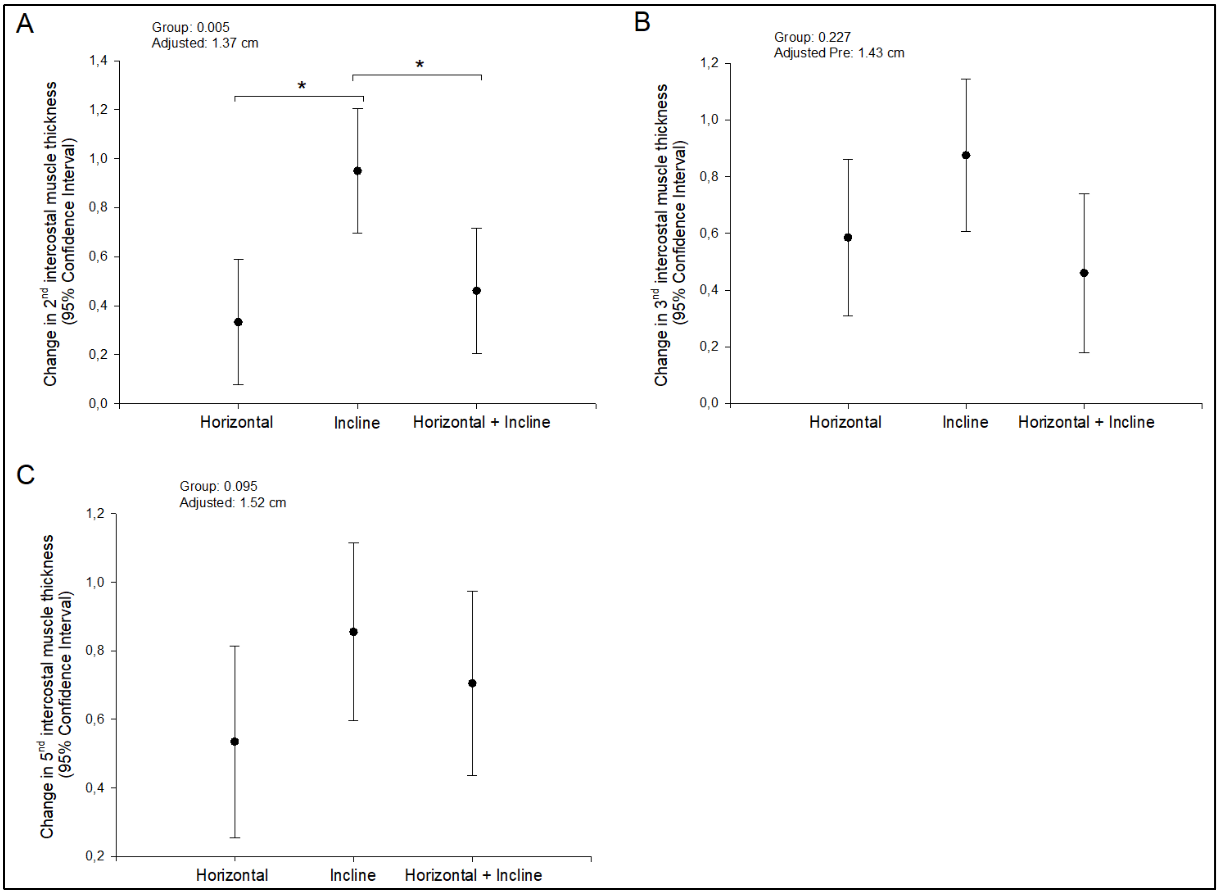

Figure 4. The pre to post change in muscle thickness at the 2nd intercostal (A), 3rd intercostal (B), and 5th intercostal (C) across the three separate training groups. Each value reported was adjusted for the baseline value with the middle dot representing the change with the variability represented by 95% confidence intervals. * represents a significant between group difference in the change in load lifted.

Table 4. EMG amplitude (μV) over time for each group.

	Pre-training	Post-training
Clavicular site for horizontal press		
Horizontal bench group	10.0 (4.2)	11.4 (5.1)
Incline bench group	10.2 (5.8)	10.1 (6.0)
Combination group	12.2 (7.1)	12.9 (6.2)
Sternal site for horizontal press		
Horizontal bench group	192.0 (83.3)	242.1 (79.1)
Incline bench group	237.0 (166.3)	210.2 (145.6)
Combination group	282.9 (247.4)	225.1 (220.1)*
Clavicular site for incline press		
Horizontal bench group	12.5 (11.6)	11.3 (11.4)
Incline bench group	7.8 (4.2)	8.8 (5.5)
Combination group	10.0 (5.7)	9.4 (5.2)
Sternal site for incline press		
Horizontal bench group	98.9 (48.2)	110.5 (43.9)
Incline bench group	145.0 (110.2)	150.3 (105.5)
Combination group	199.8 (174.3)	195.0 (144.9)

Mean (Standard Deviation).

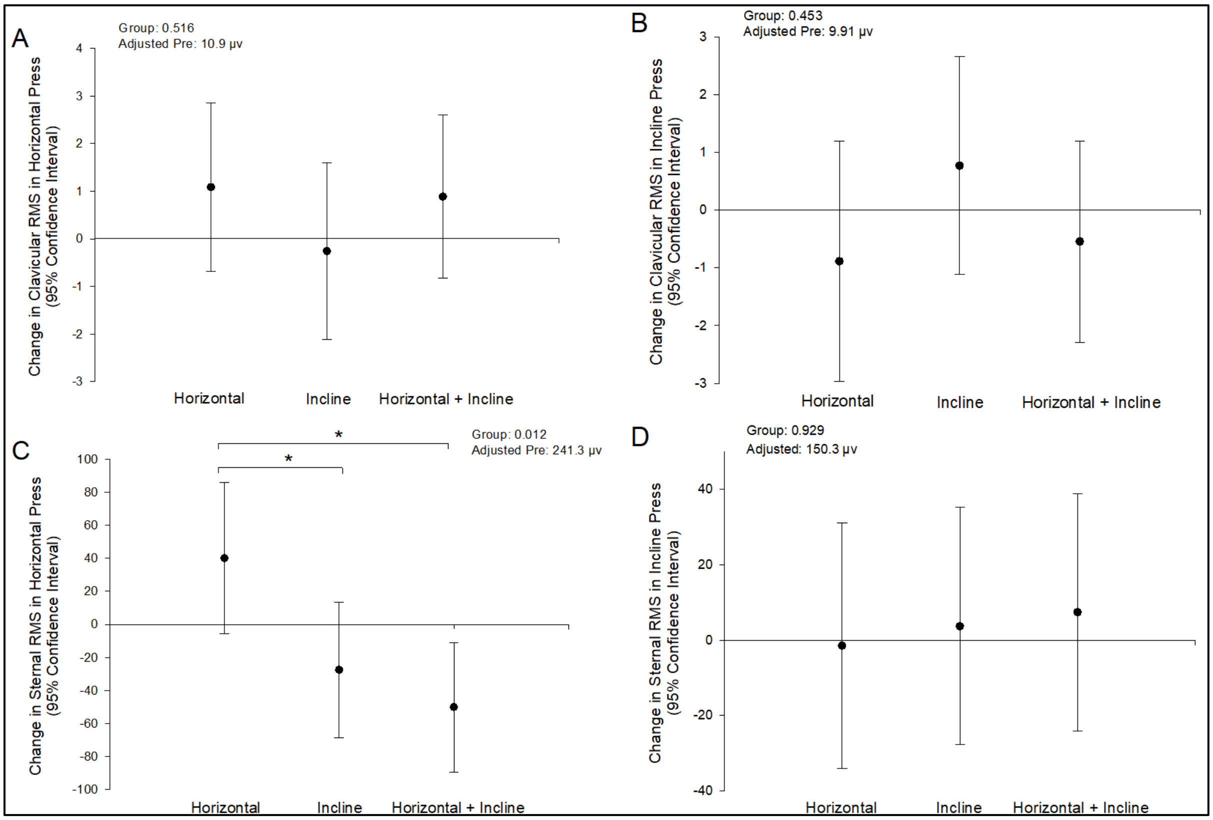

Figure 5. The pre to post change in surface EMG amplitude at the clavicular site for the horizontal (A) and incline (B) bench press across the three separate training groups. The pre to post change in surface EMG amplitude at the sternal site for the horizontal and incline bench press across the three separate training groups is found in part C and D, respectively. Each value reported was adjusted for the baseline value with the middle dot representing the change with the variability represented by 95% confidence intervals. * represents a significant between group difference in the change in load lifted.

DISCUSSION

The current study sought to evaluate the neuromuscular adaptations in untrained young men to horizontal bench press exercise, incline bench press exercise, or a group training with both. Outside of two measurements, there were no differences for changes in muscle thickness or changes in surface EMG amplitude. Although our original hypothesis was that the combination of both bench press exercises would maximize training adaptations, our findings did not find support for this contention with the variables measured within this study. This hypothesis was based in previous studies suggesting that both exercises should be performed to maximize the training stimulus, thus leading to greater muscle growth and strength gains (33). However, it should be considered with some caution, since greater surface EMG amplitude do not necessarily mean greater motor unit recruitment (34). Additionally, according to these authors, further investigation is required in order to elucidate if chronic adaptations can be inferred from acute changes in surface EMG amplitude. To the authors' knowledge, this is the first study which examined the chronic effects of horizontal bench press exercise, incline bench press exercise, and a group performing both on changes in muscle size and surface EMG amplitude of the pectoralis major. Thus, the current findings cannot be directly compared to previous studies.

Although both horizontal and incline bench press require similar shoulder horizontal adduction and elbow extension, the difference in bench angle between both exercises affect humerus position, resulting in different exercise loads and EMG amplitudes (16,19,33). These differences are a consequence of the activation of the infraspinatus, the subscapularis, and the teres minor muscles to reduce glenohumeral compression when the humerus is elevated, whether in forward flexion or abduction (16). When those muscles are recruited during humerus elevation, they also generate a force vector that reduces the resultant force generated by the anterior deltoid and the clavicular portion of the pectoralis and supraspinatus (16,19). Due to these neuromuscular specificities, a combination of bench press exercises at different angles has been recommended in order to maximize EMG amplitude and then, muscle adaptations (22,33). The present results did not support this statement with changes in non-specific strength, since isometric strength gains were not different across groups. Of note, the change in load lifted in the first set was greater within the group training exclusively with the incline bench pressure compared to the combination group. This might provide support for the importance of training specificity, however, this same effect was not observed for changes in load lifted in the horizontal bench press. This, along with the post-hoc nature of the analysis, suggests that caution is needed when interpreting that particular finding.

Traditionally it has been stated that strength changes from exercise are initially due to neural adaptations followed by contributions from muscle growth (18,26). Although muscle growth is thought to be an important mechanism of strength gain, the experimental evidence for this claim is non-existent and recent work suggests that changes in muscle size may not be playing an influential role for changing strength (5,23). The current study used changes in surface EMG amplitude as an estimate of neural adaptation and changes in muscle thickness as a measure of muscle growth. Overall, our results found that the changes in these variables were not different between groups. Whether the change in surface EMG amplitude and muscle thickness contributed to a change in muscle strength cannot be inferred from the current study design. However, what can be stated is that in this sample, there were little differences in the changes observed between each group.

It is important to note that the primary outcome for muscle performance was assessed using a non-specific strength test (i.e., isometric). The authors opted for the isometric strength test because it presents good intra and inter-session EMG reliability in bench press assessment with maximal loads (3) and previous studies do not indicate satisfactory inter-session for EMG dynamic analysis (20). However, it is important to note that the exercise was completed using isoinertial exercise and not isometric. It is not known if differences between groups would be detected using a specific strength test (i.e. 1RM test) rather than a more general test of strength (i.e. isometric). Another limitation of the present study is that muscle activation was inferred from surface EMG amplitude. Differences in neural drive cannot necessarily be inferred from this estimate (25) and this variable should be interpreted with this in mind. Lastly, muscle size was estimated via B-mode ultrasound in the current study rather than the gold standard estimate of magnetic resonance imaging. Previous work has found small differences between the two estimates, however, it was indicated that the conclusions produced would be similar (8,24).

In summary, the results of the current study demonstrated that horizontal and incline bench press exercises, or a combination of both exercises lead to similar isometric strength gains in untrained young men. It is noteworthy that the current study examined the short-term response to resistance training, and it is not known whether the specific adaptations in EMG amplitude and muscle growth observed in each group would differ with longer-term resistance training. Future studies could also examine how these changes might also contribute within the task each group was specifically training by evaluating, for instance, the 1RM or 10RM strength.

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