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Effect of pre-fatiguing the triceps brachii on subsequent strength performance and myoelectric activity in the barbell, dumbbell and Smith machine bench press

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ABSTRACT

Objective: The purpose of this study was to examine the effect of pre-fatiguing the triceps brachii on subsequent strength performance and myoelectric activity in the barbell, dumbbell, and Smith machine bench press.

Method: Nineteen trained men participated of this study (27.9 ± 4.5 years; 1.72 ± 0.1 m; 80.3 ± 9.2 kg). Ten-repetition maximum loads were determined for the triceps extension as well as the barbell, dumbbell and Smith machine bench press. Three experimental protocols were performed in a randomized design. All experimental protocols began with four sets of the triceps extension (performed with a high pulley) to repetition failure followed by four sets to repetition failure for one of three bench press modalities. Two minute-rest intervals were adopted between sets and exercises. Total repetitions (work), training volume and myoelectric activity of pectoralis major, anterior deltoid, biceps brachii, and triceps brachii were recorded during each bench press modality.

Results: Significantly greater activity of the biceps brachii was observed during performance of the dumbbell bench press versus barbell and Smith machine bench press. No other significant differences were observed between protocols.

Conclusion: Therefore, considering the training volume and myoelectric activity of the synergistic muscles, similar performance across bench press modalities can be expected when preceded by performance of a triceps extension.

Keywords: Electromyography, Resistance training, Muscle performance.

Efecto de la prefatiga del tríceps braquial en el desempeño subsiguiente de la fuerza y actividad mioeléctrica en el supino recto en la barra, mancuernas y Smith Machine

RESUMEN

Objetivo: Examinar el efecto de la prefatiga del tríceps braquial en el desempeño subsiguiente de la fuerza y actividad mioeléctrica en el supino recto utilizando barra (SRB), mancuernas (SRM) y Smith machine (SMSR).

Método: En el estudio participaron 19 hombres entrenados (27.9 ± 4.5 años, 1.72 ± 0.1 m, 80.3 ± 9.2 kg). Se realizó una prueba de diez repeticiones máximas para la extensión del tríceps, así como para el supino recto utilizando barra, mancuernas y Smith Machine. Se realizaron tres protocolos experimentales en orden aleatorizado. Los protocolos consistieron de cuatro series de repeticiones de extensión del tríceps (realizado con polea alta) hasta la fatiga, seguida de cuatro series de repeticiones hasta la fatiga de una de las tres modalidades de supino. Dos intervalos de descanso de un minuto se realizaron entre series y ejercicios. Las repeticiones totales (trabajo), volumen de entrenamiento y actividad mioeléctrica de pectoral mayor, deltoides anteriores, bíceps braquial y tríceps braquial fueron registradas durante cada modalidad de supino.

Resultados: Se observó una actividad significativamente mayor del bíceps braquial durante la realización del supino recto con mancuerna versus barra y Smith Machine. No se observó ninguna diferencia significativa entre los protocolos.

Conclusiones: Por lo tanto, considerando el volumen de entrenamiento y la actividad mioeléctrica de los músculos sinérgicos, se puede esperar un rendimiento similar en las diversas modalidades de supino, cuando es precedido por la realización de una extensión de tríceps.

Palabras clave: Electromiografía, Entrenamiento fuerza, Rendimiento muscular.

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Efeito da pré-fadiga do tríceps braquial no desempenho subsequente da força e atividade mioelétrica no supino reto na barra, halteres e Smith Machine

RESUMO

Objetivo: examinar o efeito da pré-fadiga do tríceps braquial no desempenho subsequente da força e atividade mioelétrica no supino reto utilizando barra, halter e Smith machine.

Método: Participaram do estudo 19 homens treinados (27.9 ± 4.5 anos; 1.72 ± 0.1 m; 80.3 ± 9.2 kg). Foi realizado um teste de dez repetições máximas para a extensão do tríceps, assim como para o SRB, SRH e SMSR. Três protocolos experimentais foram realizados em ordem randomizada. Os protocolos consistiram de quatro séries de repetições do a extensão do tríceps (realizado com polia alta) até a falha seguida de quatro séries de repetições até a falha de uma das três modalidades de supino. Dois intervalos de descanso de um minuto foram adotados entre séries e exercícios. As repetições totais (trabalho), volume de treinamento e atividade mioelétrica de peitoral maior, deltóide anterior, bíceps braquial e tríceps braquial foram registradas durante cada modalidade de supino.

Resultados: Observou-se uma atividade significativamente maior do bíceps braquial durante a realização do supino reto halter versus barra e Smith Machine. Nenhuma outra diferença significativa foi observada entre os protocolos.

Conclusões: Portanto, considerando o volume de treinamento e a atividade mioelétrica dos músculos sinérgicos, pode-se esperar um desempenho semelhante em modalidades de supino quando precedido pela realização de uma extensão de tríceps.

Palavras-chave: Eletromiografia, Treinamento resistido, Desempenho muscular.

Introduction

Resistance training (RT) has been adopted as an effective method to develop muscular endurance, hypertrophy, strength, and power.¹ Surface electromyography (EMG) has been implemented in resistance training studies to assess myoelectric activity and firing rate of motor units;² motor unit recruitment;³ and fatigue index⁴ during resistance exercises.

The implementation of heavy loads with repetitions to exhaustion increases the recruitment of motor units, which may increase the rate of strength gains.⁵ Knowledge about the activation of certain muscle groups during resistance exercises enables coaches and practitioners to prescribe more effective and efficient (i.e., training volume/time) training programs, while not prematurely fatiguing muscle groups that will be used later during a training session.

The bench press is a fundamental exercise in a RT program. This exercise can be performed with different modes (i.e., barbell, dumbbells, and Smith machine). Despite similar kinematics, each bench press modality may promote distinct myoelectric responses.³ Bench press using barbell promotes lateral forces directed toward the ends of the barbell that equals approximately 25% of the vertical force, independent of the load intensity.⁶ Lateral forces on the barbell promote activity in the triceps brachii.^{3,7} Therefore, pre-fatiguing the triceps brachii by performing a triceps extension exercise prior to a bench press, might limit the total repetitions and total volume accomplished for the bench press.

To the authors' knowledge, no studies have examined the effects of pre-fatiguing a synergist muscle group (triceps brachii) on subsequent myoelectric activity during different bench press modes (barbell, dumbbell, and Smith machine). This information would be useful to coaches and practitioners in programming. Therefore, the purpose of this study was to examine the effect of pre-fatiguing the triceps brachii on subsequent strength performance, rating of perceived exertion and myoelectric activity in the barbell, dumbbell, and Smith machine bench press.

Method

Sample

Ninety subjects participated in this study (Table 1). The inclusion criteria adopted were: a) male, b) having at least six months resistance training experience, considering that within

this period, the RT practitioner can coordinate the correct technique of the bench press and triceps pulley exercise, c) having performed at least three resistance training workouts per week consistently the preceding six months.

The subjects were instructed not to perform additional exercises for the upper limbs during the experimental period. During the first session to the laboratory, subjects were given an explanation of the experimental procedure and signed an informed consent. This study was approved by the institutional research ethics committee as Resolution 466/2012 of the National Health Council for research on human subjects.

Table 1. Anthropometric measurements and Ten-repetition maximum test exercises.

Measures	Mean± Standard Deviation
Age (years)	27.9 ± 4.5
Height (m)	1.72 ± 0.1
Body Mass (kg)	80.3 ± 9.2
Body Mass Index (kg/m ²)	26.9 ± 1.9
Experience with RT (years)	7.6 ± 4.6
Barbell Bench Press 10RM (kg)	81.5 ± 9.9†‡
Smith machine Bench Press 10RM (kg)	74.6 ± 8.1
Dumbbells Bench Press 10RM (kg)	70.3 ± 8.5
Triceps extension 10RM (kg)	35.1 ± 4.4

10RM: Ten-repetition maximum; ‡ significant difference for the Smith machine bench press; † significant difference for the dumbbell bench press.

Experimental Design

Ten Repetition Maximum Test (10RM) load was determined for each subject in the barbell bench press

(BBP), dumbbell bench press (DBP), Smith machine bench press (SMBP), and high pulley triceps extension (TE). The 10RM tests were conducted over six sessions after the anthropometric measurements session, with 48 hours between sessions in the following order: Sessions 2 and 5 - SMBP + TE, Sessions 3 and 6 - BBP, and Sessions 4 and 7 - DBP. The SMBP and TE were performed with Life Fitness equipment (Brunswick Company, Franklin Park, Illinois, USA). The 10RM tests were performed in five attempts for each exercise on a particular day, with five minutes rest between attempts and ten minutes rest between exercises (SMBP and TE).⁸ The biacromial breadth was adopted to standardize the positioning of the grips. During the tests and retests, the body segments of the head, shoulder girdle and buttocks remained flat on the bench.⁷ A metronome was used to standardize repetition speed; given that different paces of execution may influence the electromyographic signal, it was decided to control the movement at a steady pace of four seconds per repetition (two seconds for the concentric phase and two seconds for the eccentric phase).³ To minimize possible errors in the 10RM tests, the following strategies were adopted: (a) subjects received standardized instructions regarding exercise technique,

(b) the exercise technique during all testing sessions was monitored and corrected if necessary, (c) subjects received verbal encouragement during the tests, and (d) the mass of all the weight plates, bars (barbell and Smith machine) and dumbbells used was determined with a precision scale.^{3,9} The highest loads achieved during the test and retest sessions were used as the 10RM.

The biacromial distance was adopted to standardize the grip positioning. During the tests and retest sessions, the body segments of the head, shoulder girdle and gluteus should remain flat on the bench.⁷ For the barbell bench press and Smith machine bench press, the complete movement was valid when the bar touched the chest in the eccentric phase and the complete extension of the elbows in the concentric phase. For the dumbbell bench press, the complete movement was valid when the dumbbell screws were aligned with the chest in the eccentric phase and the full extension of the elbows in the concentric phase. The evaluators monitored repetition performance during all protocols.

Electromyography data of the pectoralis major (PM), anterior deltoid (AD), triceps (TB) and biceps brachii (BB) were collected for all protocols on mode variations in the bench press. The electrodes were positioned according to the recommendations of Cram et al.¹⁰ The electrode attachment site was shaved, cleaned with alcohol and slightly abraded to facilitate the attachment and conduction of the surface electrodes (trace Kendal Medi 200; Tyco Healthcare, Pointe-Claire, Canada). All EMG measurements were taken on the right side of the subject.¹¹ The impedance after attaching the electrodes was not greater than 5k Ω .¹² The impedance was observed between pairs of electrodes using a frequency signal of 25-Hz.

For the acquisition of muscle activity, EMG signals were collected using a MyoSystem™ 1400A with 8 input channels. The EMG signal was filtered with a band pass between 20 and 450Hz. The sampling rate of the signal was 1000 Hz. The RMS values (Root Mean Square) obtained for each muscle and protocol were normalized to the peak value obtained in each bench press mode (PM, AD, TB and BB), so that the signal intensity was presented as a percentage of the peak activity.¹³

The study was a randomized crossover design. The subjects attend a total of ten sessions. During the first session, anthropometric measurements were collected for all subjects (body weight, height, body mass index). The second through seventh sessions were for the purpose of testing and retesting 10RM loads for the experimental exercises. Forty-eight hours following the last 10RM testing session, the eighth through tenth sessions consisted of the three experimental protocols, administered in random order 48 hours apart. Each protocol consisted of four sets of the TE (in a standing position) followed by four sets of the BBP, DBP, or SMBP. The total work and training volume (load x repetitions x sets) were recorded for each bench press mode; while myoelectric activity was measured for the PM, AD, TB and BB.

The subjects performed the first of three experimental protocols in random order, which included: P1) triceps extension + Smith machine bench press (TSM); P2) triceps extension + barbell bench press (TBP); P3) triceps extension + dumbbell bench press (TDB). A rest interval of 48 hours was given between each experimental session. Each protocol was preceded by a warm up set of twenty repetitions at 40% of the 10RM load for the barbell bench press exercise.³ All experimental protocols consisted of four sets of the TE to repetition failure followed by four sets to repetition failure for one of three bench press modalities. Two minute-rest intervals were adopted between sets and exercises. The number of repetitions completed in each set, exercise and protocol were recorded. The total work was defined as the sum of all repetitions performed during the four sets for each bench press mode.³ A metronome was used to control the repetition speed; the movement was controlled at a steady pace of four seconds per

repetition (two seconds for the concentric phase and two seconds for the eccentric phase).³

Statistical analysis

The data were presented as the mean \pm standard deviation. The reliability of the test-retest 10RM was performed using the intraclass correlation coefficient ($ICC = (MS_b - MS_w) / [MS_b + (k-1)MS_w]$), where MS_b = mean-squared between, MS_w = mean-squared within, k = average group size.¹⁴ The cutoff points for classification of the ICC were defined considering: weak reliability ($ICC \leq 0.40$); moderate reliability ($0.41 < ICC \leq 0.75$); and excellent reliability ($ICC > 0.75$).¹⁵ The Shapiro-Wilk test and homoscedasticity (Bartlett criterion) showed that all variables presented normal distribution and homoscedasticity. A two-way repeated measures analysis of variance [protocol (3) x sets (4)] was used to determine if there were significant effects or interactions in repetition performance, EMG muscle activity and training volume. Bonferroni post-hoc tests were adopted for multiple comparisons. The level of statistical significance was set at $p \leq 0.05$ for all tests. Statistical analysis was performed with SPSS version 20.0 (Chicago, IL, USA).

Results

The sample consisted of nineteen trained men. The ICCs for test-retest 10RMs were SMBP = 0.97, BBP = 0.98, DBP = 0.95 and TE = 0.97. Significant differences were observed in the 10RM load between bench press modes ($F = 12.904$, $p = 0.002$) (Table 1). The same 10RM load was adopted to perform the TE exercise in all protocols.

No significant main effects were noted between protocols in the total work ($F = 0.460$, $p = 0.639$) and training volume ($F = 0.362$, $p = 0.702$). Across bench press, modes, no significant main effect between protocols and sets were noted for the repetitions per set ($F = 0.284$, $p = 0.756$), total work ($F = 13.342$, $p = 0.420$) and training volume ($F = 17.000$, $p = 0.204$) (Figure 1).

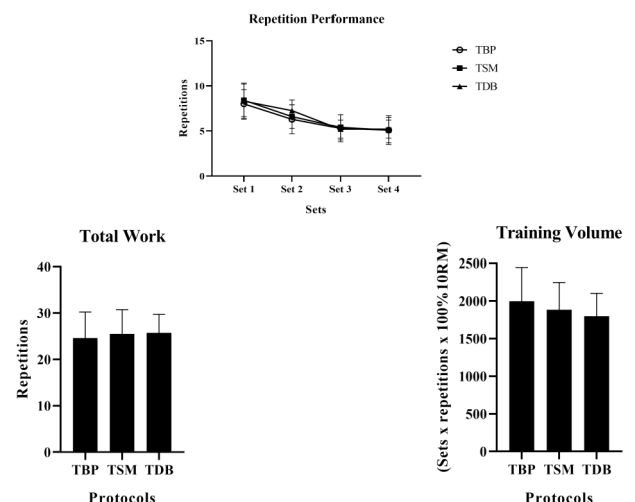


Figure 1 Repetition performance, total work and training volume during the bench press modes. TBP: Triceps extension + Barbell Bench Press; TSM: Triceps extension + Smith Machine Bench Press; TDB: Triceps extension + Dumbbell Bench Press.

The myoelectric activity is presented in Figure 2. For the BB muscle, greater activity was observed under TDB vs. TSM and TBP over the 4 sets ($F = 17.845$, $p < 0.001$), respectively.

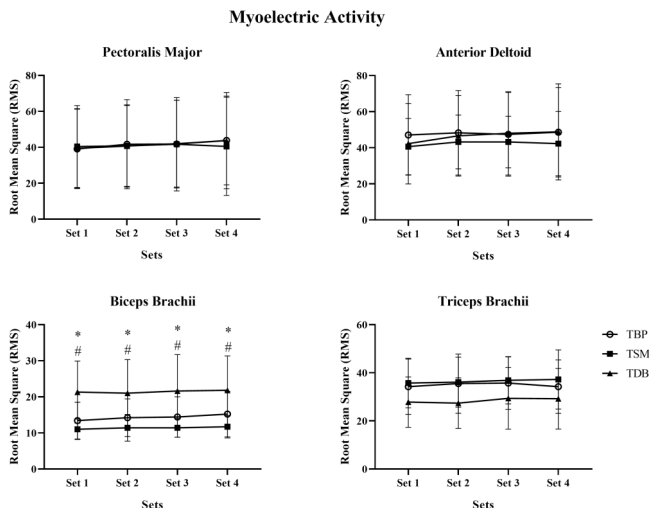


Figure 2. Root Mean Square percentage standardized of the muscle groups during the different modes of bench press exercise. TBP: Triceps extension + Barbell Bench Press; TSM: triceps extension + Smith Machine Bench Press; TDB: Triceps extension + Dumbbell Bench Press; * Significant difference for the barbell bench press; # significant difference for the Smith machine bench press.

Discussion

The purpose of this study was to examine the effect of pre-fatiguing the triceps brachii on subsequent strength performance, rating of perceived exertion and myoelectric activity in the barbell, dumbbell, and Smith machine bench press. The main findings of the present study were the significant differences only for biceps brachii myoelectric activity for the dumbbell bench press versus the barbell and Smith machine bench press. It was hypothesized that pre-fatiguing the triceps brachii would negatively affect subsequent performance for the DBP (versus the BBP and SMBP) due to the stabilizing action of the triceps and biceps on the shoulder joint. Our hypothesis was rejected, due to the lack of main effects between protocols and sets for repetition performance and myoelectric activity.

Regarding the 10RM loads, the BBP load was significantly greater versus the SMBP and DBP, respectively. These findings were consistent with Satterbakken et al.⁷ who observed a higher 1RM load when the bench press was performed with a barbell versus dumbbell and Smith machine. Cotterman et al.¹⁶ found that the Smith machine, often characterized by one degree of freedom, maintains a standard and limited range of motion, reducing recruitment of primary muscles, and consequently presenting a lower 10RM load. For the DBP, the lower 10RM load might be associated to the greater stability requirements that decreases the net torque and the ability to lift the weight.⁶

In the current study, there were no significant differences in the repetitions per set, training volume and total work, between bench press modes. Our results were in contrast with the Augustsson et al.¹⁷ who observed a decrease in muscle electrical activity and a decrease in repetition performance when a multi-joint exercise (leg press) was preceded by a single-joint exercise (leg extension). Gentil et al.¹⁸ found no significant changes in total bench press repetitions when preceded by a single-joint exercise (peck-deck). In the current study, pre-fatiguing the triceps brachii appeared to affect subsequent bench press performance to the same extent, irrespective of the mode.

Regarding the myoelectric activity, there were no significant differences between bench press modes for the PM, AD and TB. Gentil et al.¹⁸ found no significant differences in myoelectric activity for the pectoralis major when the barbell bench press was preceded by a chest fly (peck-deck) or the reverse order. However, the authors reported an increase in the myoelectric activity of triceps brachii during the bench press exercise when it was preceded by the by the peck-deck. Rosa et al.¹⁹ found significant differences in myoelectric activity of the pectoralis major during the BBP exercise when preceded by an exercise for the triceps brachii. Rocha Junior et al.²⁰ reported an increase in EMG activity of the vastus lateralis when the 45-degree angled leg press was performed before the leg extension with low and moderate load intensities.

Fleck and Kraemer¹ observed that, as the synergist muscles fatigue, small muscle groups provide a lower contribution in the movement, maximizing the stress on large muscle groups. In the current study, pre-fatiguing the triceps brachii was designed to place greater stress on the pectoralis major. We found similar PM activity for all bench press modes. In contrast to the current study, Farias et al.³ applied the reverse order for exercises in which the triceps extension was performed following different bench press modes. The authors observed that the DBP + TE condition resulted in significantly greater total work as well as increased electrical activity of PM and BB. Whereas, the SMBP + TE conditions resulted in significantly higher electrical activity of the AD and TB. Thus, it can be inferred that when the TB was pre-fatigued, the stress on the larger muscle groups was maximized, and there were no significant differences between bench press modes in PM, AD and TB activation.

There were significant differences in the myoelectric activity of the BB for the DBP versus the BBP and SMBP. When using a barbell, the external reactive forces present a medial-lateral component due to the grip, reducing the torque of the stabilizing muscles of the shoulder, increasing the recruitment of the triceps brachii, due to lateral forces.²¹ In contrast, when performing the bench press exercise with dumbbells, because there is no lateral forces acting, the external reactive forces points straight downward, increasing the internal torque produced by the stabilizing shoulders muscles, promoting greater biceps brachii recruitment, which acts as a neutralizer avoiding the elbow extension.²¹ The BB acts as a neutralizer when the elbow joint flexes during the eccentric phase of a dumbbell bench press. The short head of the biceps brachii originates on the coracoid process of the scapula and assists with shoulder horizontal adduction, which is more pronounced during the DBP versus the BBP and SMBP.²²

The present study also had some limitations such as the non-control of the use of ergogenic resources and the daily activities performed by the participants. However, they were asked not to train the upper limb muscle groups during the study period so that there was a daily routine standardization during training sessions. Thus, there was verbal feedback from participants regarding the maintenance of their physical activity routines.

In conclusion, pre-fatiguing the triceps brachii before performing various modes of the bench press (barbell, Smith, dumbbell) did not affect repetition performance between protocols or sets. Despite subtle differences in force vectors between bench press modes, performing a high pulley triceps extension prior to a bench press does not result in significant differences in total repetitions, total volume, muscle activity, or rating of perceived exertion, irrespective of the bench press mode. Therefore, when prescribing a resistance training program for upper body muscles, pre-fatiguing the triceps brachii may not influence the strength performance and myoelectric activity of the prime movers in the bench press exercise regardless of the mode adopted.

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