Effects of Pre-exhaustion on the Patterns of Muscular Activity in the Flat Bench Press

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Abstract

Gołaś, A, Maszczyk, A, Pietraszewski, P, Stastny, P, Tufano, JJ, and Zając, A. Effects of pre-exhaustion on the patterns of muscular activity in the flat bench press. *J Strength Cond Res* 31 (7): 1919–1924, 2017—Pre-exhaustion (PE) has been applied in resistance training (RT) to manipulate the order of performing 2 resistance exercises, a single-joint exercise to momentary exhaustion, followed by a multi-joint movement that includes the same muscle group. This method ensures greater recruitment of muscles or muscle groups in the multi-joint exercise to further increase muscle strength and overcome strength plateaus. The purpose of the present study was to investigate muscle activity by electromyography during high-intensity (95% of 1 repetition maximum [RM]) bench press (BP), before and after PE of the pectoralis major (PM), anterior deltoid (AD), and triceps brachii (TB) muscles to determine the effects of PE of the prime movers. Eight healthy athletes, experienced in RT, participated in the study. There were 4 sessions in the experiment. Session 1 was aimed at determination of 1RM during a flat BP. Sessions 2, 3, and 4 consisted of performing a BP after PE of the muscles studied by the incline dumbbell fly, front deltoid raise, and lying triceps extension exercise. Peak concentric TB activation after TB PE (mean ± *SD*, 147.76 ± 18.6%) was significantly greater by analysis of variance ($\eta^2 = 0.82$, $F = 5.45$, $p = 0.004$) compared with peak TB activation (114.77 ± 19.4%) before TB PE. The statistical analysis for PM and AD did not show any significant differences. Coaches should not expect the usefulness of PE protocol to elicit higher PM or AD activity or fatigue, but they can use it to increase TB activity before high-intensity BP exercise.

Key Words resistance training, triceps brachii, pectoralis major, anterior deltoid, electromyography, neuromuscular fatigue

Introduction

Resistance training (RT) is used to develop muscular strength, increase external power output, and induce skeletal muscle hypertrophy (6). Planning and developing a RT program is based on creating combinations of basic training variables, such as the number of repetitions and sets performed, the external loads lifted, and the choice and order of exercises (5). Recently, numerous studies have evaluated the effect of exercise order on muscular contraction (contractibility) and have shown that exercise order can increase power output or strength (22,25), yet decrease repetition performance (15). One way of manipulating the exercise order is to perform a single-joint exercise to momentary exhaustion, followed by a multi-joint movement that includes the same muscle group: a method known as pre-exhaustion (PE) (5). The hypothetical mechanism underlying the use of PE during RT is that muscles within the previously "exhausted" motor units (MUs) may not be able to generate enough force to concentrically complete the multi-joint movement, possibly requiring higher threshold MUs to be used to compensate for the loss of functionality of the fatigued MUs (16,18). As high-threshold MUs are said to include more type II muscle fibers than low-threshold MUs, preferential recruitment of high-threshold MUs may result in greater maximal strength and hypertrophy compared with training in which primarily low-threshold MUs are used. Therefore, PE may been used in place of traditional RT to further increase muscle strength and overcome strength plateaus (1).

The scientific community has focused on PE using the bench press (BP) exercise because of the fact that many athletes perform the BP to develop upper body strength. As the BP is such a popular exercise among individual and team sport athletes, many coaches and researchers are interested in how altering acute program variables can affect resultant neuromuscular responses. Depending on anthropometric variables and movement technique, muscular activity patterns vary during the BP, but researchers agree that the 3 primary muscle groups involved during the BP include the pectoralis major (PM), anterior deltoid (AD), and triceps brachii (TB) (13,26,28). Although the

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31(7)/1919–1924

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analysis of muscular activity during the BP has been described extensively in the literature (13,19,20,24,29), research investigating the effects of PE during the BP is scarce. Only 2 studies have assessed muscle activity during the BP before and after PE: one study using 10 repetition maximum (RM) loads for the peck deck as a PE exercise (8) and the other using a 10RM load during the dumbbell fly exercise (2). In both cases, only one of the primary movers during the BP (the PM) was "exhausted," and the results of both studies showed that PE of the PM increased TB activity during a subsequent 10RM BP. In contrast to the original hypothesis of PE increasing MU recruitment in the pre-exhausted muscle group, these data led the authors to speculate that higher threshold MUs had to be recruited in the TB to meet the concentric demands of the subsequent 10RM BP because the PM may not have been able to produce as much force as before the PE BP.

Although these studies indicate that PE may not increase MU recruitment of the pre-exhausted muscle group, they do show that other muscle groups may need to produce more force to meet the demands of the subsequent exercise. As mentioned, the BP includes 3 main muscle groups, but the effect of PE has not been investigated in the TB or AD (2,8). Additionally, these experiments (5,23) used 10RM BP loads before and after PE, indicating that the studies may have been designed to primarily investigate the acute effects of PE on the possibility of increasing muscular hypertrophy. However, the activation of higher-threshold MUs also plays a role in the development of maximal strength, meaning that the investigation of PE on a subsequent heavy multi-joint movement is fully justified.

Therefore, the purpose of the present study was to investigate muscle activity during high-intensity BP (95% 1RM), before and after PE of the PM, TB, and AD to determine the effects of PE of the prime movers. Based on previous data showing that PE of the PM results in increased TB activity (2,8), it was hypothesized that PE of the AD and TB would result in increased activity of the PM, whereas PE of the PM would result in increased activity of the TB during a single high-intensity BP repetition (95% of 1RM).

Methods

Experimental Approach to the Problem

The measurements, spanning across 4 sessions, were performed in the Laboratory of Muscular Force and Power at the Academy of Physical Education in Katowice using a cross-sectional design in January and February, 2016. Session 1 included 1RM testing of the flat barbell BP. Sessions 2, 3, and 4 consisted of performing a single repetition of the BP with 95% 1RM before and after PE of the PM, TB, and AD. Each of these sessions was randomized and included PE of a different muscle group. The lying triceps extension exercise was used to pre-exhaust the TB, the incline dumbbell fly to pre-exhaust the PM, and the front deltoid raise to pre-exhaust the AD.

Subjects

Eight healthy male athletes from various sport disciplines who were experienced in RT for at least 3 years (basketball players, mixed martial arts, track and field) participated in the study (26 ± 3.8 years [range 23–34 years], 85 ± 5 kg, 176 ± 9.5 cm). Each subject had been using the exercises included in the present study for at least 3 months before data collection. The participants did not perform any resistance exercises for 72 hours before testing, and all experimental sessions were separated by 7 days. All subjects were informed verbally and in writing about the procedures and possible benefits and risks of the tests and provided written consent before they were included in the study. The study received the approval of the Bioethics Committee at the Academy of Physical Education in Katowice.

Session 1

During session 1, subjects completed a standardized warm-up protocol including 5 minutes on a hand-cycle ergometer (heart rate between 130 and 140 $b \cdot min^{-1}$) followed by 15, 10, and 5 repetitions of the BP using 40, 60, and 70% of 1RM, respectively. After the standardized warm-up, the percentage of the 1RM load was calculated based on the self-reported values by the participants. The self-reported 1RM was set according to the information given by the participants on maximal lifts performed in the previous 6 months. Next, 1RM BP was determined according to the protocols of van den Tillaar and Saeterbakken (28).

After the 1RM BP, the 1RM was tested in randomized order for TB using the lying triceps extension, AD using the front barbell deltoid raise, and for the PM using dumbbell fly. Participants performed 12 repetitions at 50% of 1RM, 6 repetitions at 70% of 1RM, and 1 repetition at 85% of 1RM on exercise estimated for 1RM. The rest periods were between 3 to 5 minutes to avoid the potential effect of fatigue. When the self-reported 1RM was successful, a trial with an additional load of 2.5–5 kg was performed. When the initial trial was unsuccessful, the weight was decreased by 2.5–5 kg. A total of 2 to 3 trials were performed per participant for each exercise.

Sessions 2, 3, and 4

These sessions were randomized and included a different PE protocol aimed at exhausting a particular muscle group: the incline dumbbell fly, front deltoid raise, and lying triceps extension. To begin sessions 2, 3, and 4, the participants completed the same warm-up as they did during session 1, and after 5 minutes of rest, they performed a single repetition of the BP with a load of 95% 1RM. Following previous recommendations for resting after a heavily loaded exercise (23), participants rested for 5 minutes and then performed the session's PE protocol that consisted of 4 sets of 10RM (1,2,8), which is approximately 70% of 1RM load (4) with 2-minute rest intervals between sets. After resting for 5 minutes after the final PE repetition, a single repetition of the BP was performed with 95% 1RM. After 3–5 minutes,

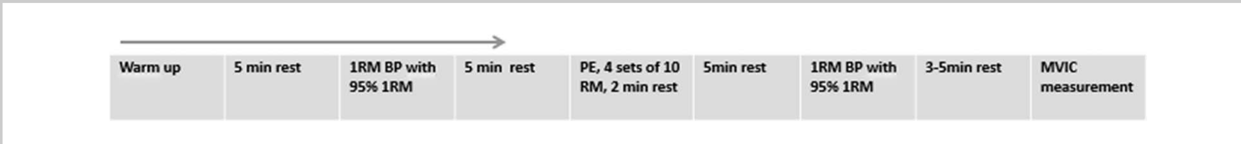

Figure 1. The procedures flow chart in sessions 2, 3, and 4. RM = repetition maximum; BP = bench press; PE = pre-exhaustion; MVIC = maximal voluntary contraction.

a maximum voluntary isometric contraction (MVIC) was performed for each of the 3 muscles for the normalization of electromyography (EMG; Figure 1).

The movement speed during all exercises was preset using an electronic metronome (Korg MA-30; Korg, Melville, NY, USA) at 1 second eccentric phase followed by a maximal velocity concentric phase. As previously stated, the purpose of this study was to determine the effects of PE on muscle activity during a subsequent strength-based activity using 95% 1RM. Therefore, in contrast to previous studies in which subjects immediately performed the subsequent multi-joint movement using loads of approximately 70% 1RM, 5 minutes of rest was provided after the completion of the final PE repetition in the present study, in line with previous recommendations when maximal loads are used (23). The participants were spotted during each session by the research supervisor, who also motivated the athletes verbally. Although a 10RM load was used, all participants were able to complete at least 8 repetitions during all 4 sets of every PE protocol.

Electromyography

An 8-channel Noraxon TeleMyo 2400 system (Noraxon USA, Inc., Scottsdale, AZ, USA; 1500 Hz) was used for the recording and analysis of EMG activity. The activity was recorded during the concentric and eccentric phases of the BP for the PM (sternocostal fibers), AD, and TB (lateral head). Before placing the gel-coated self-adhesive electrodes (Dri-Stick Silver circular sEMG Electrodes AE-131; NeuroDyne Medical, USA), the skin was shaved, abraded, and washed with alcohol. The electrodes (11 mm contact diameter and a 2-cm center-to-center distance) were placed parallel to the direction of the underlying muscle fibers according to the recommendations by SENIAM (11). The EMG signals were sampled at a rate of 1,000 Hz. Signals were band pass filtered with a cut off frequency of 8 and 450 Hz, after which the root mean square (RMS) was calculated. All electrodes were located on the right side of the participant, regardless of whether it was the dominant side. The PM electrodes were placed on sternocostal fibers, 4 cm medial to the axillary fold (21), AD electrodes were placed 1.5 cm distal and anterior to the acromion (24,27), and TB electrodes were placed medial and inferior over the muscle belly (7). The grounding electrode was placed on the olecranon. Synchronized video recording was used for identification of the beginning and completion of the movement.

At the end of sessions 2–4, 2 sets of 2- to 3-second tests of MVIC with 2-minute rest intervals were performed to normalize EMG recordings according to the SENIAM procedure (11). The TB MVIC was obtained during lying triceps extension with 90° elbow flexion, the AD MVIC at 90° seated arm flexion, and the PM MVIC during an isometric BP at 90° elbow flexion. All MVIC tests were performed against a fixed multi-press bar.

The EMG analyses were based on mean RMS and peak RMS during the eccentric and concentric phases of BP (2) before and after exhaustion with 95% 1RM and expressed as a percentage of MVIC (%MVIC). The EMG results of all measured muscles during 1 repetition BP with 95% 1RM load before and after the PE protocol (expressed in %MVIC) have been included in the statistical analyses.

Statistical Analyses

The dependent variables were EMG peak and mean for both the eccentric and the concentric phases of the pre- and post-BP during all 3 exercise protocols. The data were processed using Statistica software and presented as mean values with *SD*s. The Shapiro-Wilk, Levene and Mauchly's tests were used to verify the normality, homogeneity, and sphericity

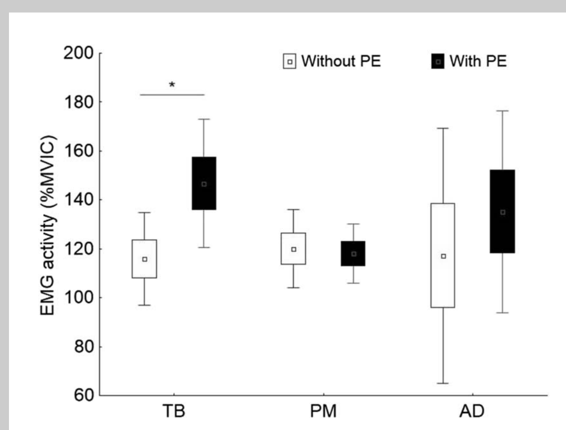

Figure 2. Peak muscle activity of the triceps brachii, pectoralis major and anterior deltoid during the flat bench press using 95% 1 repetition maximum with and without PE. PE = pre-exhaustion; TB = triceps brachii lateral head; PM = pectoralis major sternoclavicular fibres; AD = anterior deltoid; EMG = electromyography; %MVIC = percent of maximal voluntary contraction.

Table 1. Peak muscle activity for the PM, AD, TB muscles for the bench press exercise with and without PE with the load of 95% 1RM.*

	PM, mean ± *SD*		AD, mean ± *SD*		TB, mean ± *SD*	
	Without PE	With PE	Without PE	With PE	Without PE	With PE
EMG (MVIC %)	120 ± 13	118 ± 8	117 ± 44	135 ± 36	116 ± 18	147 ± 19
Δ without PE − PE (%)	−2		18		31	

*PM = pectoralis major sternoclavicular fibres; AD = anterior deltoid; TB = triceps brachii lateral head; RM = repetition maximum; PE = pre-exhaustion; EMG = electromyography; MVIC = maximal voluntary contraction; Δ = value difference between values with and without pre-exhaustion.

of the sample's data variances, respectively. A 2-way (with and without PE) repeated-measures analysis of variance was performed for each variable and each muscle followed by Tukey's post hoc tests. The statistical analysis was aimed at determination of dependent variables differentiated by the independent variable (14). Effect sizes (partial eta squared, η^2) were reported for results, where appropriate. Parametric effect sizes were defined as large if $d > 0.8$, moderate if $d = 0.8–0.5$, and small if $d < 0.5$ (14). The statistical significance was set at $p \leq 0.05$.

Results

Data were normally distributed ($W = 0.89$ for PM, $W = 0.91$ for AD, and $W = 0.93$ for TB) and the assumption of sphericity was not violated ($\chi^2 = 3.44$ for PM, $\chi^2 = 3.14$ for AD, and $\chi^2 = 3.65$ for TB). There was a significant main effect of PE on peak concentric TB activation ($\eta^2 = 0.82$, $F = 5.45$, $p = 0.004$) in TB PE protocol (Figure 2). Peak concentric TB activation following TB PE (mean ± *SD*, 147.76 ± 18.6%) was significantly greater compared with peak TB activation (114.77 ± 19.4%) before TB PE (Table 1 and Figure 2). The statistical analysis for PM and AD did not show significant differences in peak or mean concentric and eccentric RMS before and after PE.

Discussion

The main finding of this study was that TB activity during high-intensity BP increased after TB PE exercise, but PM and AD did not increase their activity in response to any PE protocol. The finding that the PM and AD did not respond to any PE protocol is in agreement with previous studies (2,8). Moreover, it is possible to conclude that only TB activity can be increased in high-intensity BP following a PE protocol. Therefore, when coaches or athletes aim to increase the activity of the prime movers using PE protocols, only the TB may respond accordingly. Although hypothetical, it is possible that increased TB muscle activity during training may enable higher threshold MUs to be used more often, increasing the likelihood of such MUs being used during high-intensity performance such as the shot put or javelin throw.

Previous studies have indicated that the TB may be the muscle group that is responsible for limiting performance during the BP, suggesting that although the TB is considered to be a smaller muscle group than the PM, it can be considered as the performance-limiting muscle in the kinetic chain for BP performance (3,13). The PM, TB, and AD amplitude in the BP has been reported to increase as load and speed increases (12,17,19); however, increasing the external load increased TB and AD activity but did not affect PM activity (10,13). It has also been shown that the TB showed greater normalized EMG activity (above 100% MVIC) than the PM (below 80% MVIC) and AD (below 100% MVIC) during 1RM lifts (3). Therefore, the greater TB activity seems to be appropriate in high-intensity lifts, where our finding that only TB activity can be increased by the PE protocol can be useful for justifying the need for TB PE workout session included in RT program aimed to increase 1RM BP performance. However, the AD and PM have been shown to be responsible for surpassing the sticking region in 6RM BP (28) when fatigue occurs (such as fatigue of TB), but those muscles did not respond to the PE protocol in this study. Because the TB PE protocol increased TB activity in a subsequent high-intensity lift, TB PE may elicit the use of higher threshold MUs during high-intensity training sessions, possibly leading to greater gains in strength and hypertrophy compared with a protocol lacking TB PE.

A relatively constant activity of the PM in our study (Table 1) may be partly explained by the fact that the order of recruitment of MUs in multifunctional muscles with broad origins (such as the pectoralis muscles) depends on various factors, for example, the direction of the force, which has an effect on mechanical efficiency. In a study by Glass and Armstrong (9), the decline BP caused a more intensive recruitment of the sternocostal part of the PM, whereas for the opposite position (incline), the exercise activated the clavicular part of this muscle more significantly. There is some evidence that the independent synaptic input for different MUs is contained in one muscle. It should be noted that the effect of PE on AD peak activity was moderate

($\eta^2 = 0.65$), but the difference was not statistically significant ($p = 0.08$). However, the AD after AD PE protocol revealed an 18% increase in activity (Table 1) after PE which, despite the lack of statistical significance, suggests greater stability work, perhaps indicating the role of the AD in overcoming the sticking region.

A previous study (2) identified that PM PE using the 10RM dumbbell fly elicited greater TB activity during a subsequent 10RM BP but did not increase the neural activity of the PM. Our findings indicate that TB PE can result in increased TB during a 95% 1RM BP. However, not all prime movers or PE exercises can be used to succeed this effect. No significant differences were observed for the PM and AD, which is similar to previous studies (2,8) using 10RM PE protocols and 10RM pre-post measures. Therefore, it seems as though the effect of PE on neuromuscular activity is highly dependent of the loading parameters of the multi-joint exercise performed.

Coaches and athletes can expect the following after implementing a PE protocol: increased activity during moderate-intensity exercise performed to failure (10RM) of prime movers that were not targeted during PE (2,8) or an increased TB muscle activity when using low repetitions in the main exercise performed at high intensity (90–100% 1RM). However, there is a high specificity of the above mentioned effect in exercise and targeted muscle. Because in BP, only TB can be influenced by PE protocol and the effect depends on PE of other prime movers and the intensity of the main exercise.

Although the novelty of the present study's protocols shed light on the effects of PE on subsequent high-intensity performance, the data presented cannot be directly compared with other data because of differences in protocols used in previous studies (i.e., 10RM vs. 95% 1RM). However, the data of the present study give a foundation to which future studies can be compared. One limitation of the current study is that EMG can provide data for the neuromuscular aspect of the lift but provides no information regarding the metabolic response. In this manner, it would be premature to conclude that PE should be used to increase strength and hypertrophy, as the development of both comprise complex metabolic and hormonal mechanisms not measured in the present study. Nonetheless, the data of the present study show that PE of the TB may increase TB muscle activity and MU recruitment during high-intensity exercise, possibly resulting in heightened neuromuscular adaptations.

Practical Applications

The results of the present study indicate that when compared with an initial BP repetition with 95% 1RM, PE of the TB with lying triceps extensions can result in greater TB activity during a subsequent 95% 1RM flat barbell BP. The PE had an effect on AD, which further supports that PE affects the smaller prime movers but does not affect PM muscle activity during the BP exercise, which is relatively constant regardless of the PE exercise choice. Coaches can use different PE protocols but only TB activity may be influenced by TB PE during the BP. In other words, coaches should not expect the usefulness of PE protocol to elicit higher PM or AD activity or fatigue, but they can use it to increase TB activity before high-intensity BP exercise. Because of a possibility to increase MU recruitment in the TB during high-intensity BP, the 10RM PE protocol can target TB activity fatigue during 1 repetition task, resulting in improved performance.

The selection of exercise and workout protocol for successful PE has to be measured because our results do not correspond with the general belief that any prime mover exercise can be used for PE. This study shows the specific application of PE protocol, which includes the rest before the 95% maximal lift, where the lying triceps extension (French press) can elicit TB activity possibly resulting in its increased adaptation for 1RM lifts. Therefore, when athletes lack in triceps strength or activity during the BP, coaches can implement PE exercise protocols during BP training.

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References

1. Augustsson, J, Thomeé, R, Hornstedt, P, Lindblom, J, Karlsson, J, and Grimby, G. Effect of pre-exhaustion exercise on lower-extremity muscle activation during a leg press exercise. *J Strength Cond Res* 17: 411–416, 2003.
2. Brennecke, A, Guimaraes, TM, Leone, R, Cadarci, M, Mochizuki, L, Simao, R, Amadio, AC, and Serrao, JC. Neuromuscular activity during bench press exercise performed with and without the preexhaustion method. *J Strength Cond Res* 23: 1933–1940, 2009.
3. Clemons, JM and Aaron, C. Effect of grip width on the myoelectric activity of the prime movers in the bench press. *J Strength Cond Res* 11: 82–87, 1997.
4. Dos Remedios, R. *Men's Health Power Training: Build Bigger, Stronger Muscles Through Performance-Based Conditioning*. New York, NY: Rodale, 2007.
5. Fleck, SJ and Kraemer, W. *Designing Resistance Training Programs* (4th ed.). Champaign, IL: Human Kinetics, 2014.
6. Folland, JP and Williams, AG. The adaptation to strength training: Morphological and neurological contributions to increased strength. *Sports Med* 37: 145–168, 2007.
7. Frost, DM, Cronin, JB, and Newton, RU. A comparison of the kinematics, kinetics and muscle activity between pneumatic and free weight resistance. *Eur J Appl Physiol* 104: 937–956, 2008.
8. Gentil, P, Oliveira, E, De Araújo Rocha, V Jr, Do Carmo, J, and Bottaro, M. Effects of exercise order on upper-body muscle activation and exercise performance. *J Strength Cond Res* 21: 1082–1086, 2007.
9. Glass, SC and Armstrong, T. Electromyographical activity of the pectoralis muscle during incline and decline bench presses. *J Strength Cond Res* 11: 163–167, 1997.
10. Gołaś, A, Maszczyk, A, Wilk, M, and Statsny, P. Changes in bar velocity and muscular activity during the bench press in relation to the load lifted. *Cent Eur J Sport Sci Med* 11: 95–101, 2015.

11. Hermens, HJ, Freriks, B, Disselhorst-Klug, C, and Rau, G. Development of recommendations for SEMG sensors and sensor placement procedures. *J Electromyogr Kinesiol* 10: 361–374, 2000.

12. Krol, H, Golas, A, and Sobota, G. Complex analysis of movement in evaluation of flat bench press performance. *Acta Bioeng Biomech* 12: 93–98, 2010.

13. Maszczyk, A, Gołaś, A, Czuba, M, Król, H, Wilk, M, Stastny, P, Goodwin, J, Kostrzewa, M, and Zając, A. EMG analysis and modelling of flat bench press using artificial neural networks. *South Afr J Res Sport Phys Educ Rec* 38: 91–103, 2016.

14. Maszczyk, A, Roczniok, R, Waśkiewicz, Z, Czuba, M, Mikołajec, K, Zajac, A, and Stanula, A. Application of regression and neural models to predict competitive swimming performance. *Percept Mot Skills* 114: 610–626, 2012.

15. Miranda, H, Simão, R, dos Santos Vigário, P, de Salles, BF, Pacheco, MT, and Willardson, JM. Exercise order interacts with rest interval during upper-body resistance exercise. *J Strength Cond Res* 24: 1573–1577, 2010.

16. Newham, D, McCarthy, T, and Turner, J. Voluntary activation of human quadriceps during and after isokinetic exercise. *J Appl Physiol (1985)* 71: 2122–2126, 1991.

17. Newton, RU, Murphy, AJ, Humphries, BJ, Wilson, GJ, Kraemer, WJ, and Hakkinen, K. Influence of load and stretch shortening cycle on the kinematics, kinetics and muscle activation that occurs during explosive upper-body movements. *Eur J Appl Physiol Occup Physiol* 75: 333–342, 1997.

18. Nyland, J, Caborn, D, Shapiro, R, and Johnson, D. Fatigue after eccentric quadriceps femoris work produces earlier gastrocnemius and delayed quadriceps femoris activation during crossover cutting among normal athletic women. *Knee Surg Sports Traumatol Arthrosc* 5: 162–167, 1997.

19. Sakamoto, A and Sinclair, PJ. Muscle activations under varying lifting speeds and intensities during bench press. *Eur J Appl Physiol* 112: 1015–1025, 2012.

20. Santana, JC, Vera-Garcia, FJ, and McGill, SM. A kinetic and electromyographic comparison of the standing cable press and bench press. *J Strength Cond Res* 21: 1271–1277, 2007.

21. Schick, EE, Coburn, JW, Brown, LE, Judelson, DA, Khamoui, AV, Tran, TT, and Uribe, BP. A comparison of muscle activation between a Smith machine and free weight bench press. *J Strength Cond Res* 24: 779–784, 2010.

22. Sforzo, GA and Touey, PR. Manipulating exercise order affects muscular performance during a resistance exercise training session. *J Strength Cond Res* 10: 20–24, 1996.

23. Siff, MC. *Supertraining* (6th ed.). Denver, CO: Supertraining Institute, 2003. pp. 290.

24. Soncin, R, Pennone, J, Guimarães, TM, Mezêncio, B, Amadio, AC, and Serrão, JC. Influence of exercise order on electromyographic activity during upper body resistance training. *J Hum Kinet* 44: 203–209, 2014.

25. Spreuwenberg, LP, Kraemer, WJ, Spiering, BA, Volek, JS, Hatfield, DL, Silvestre, R, Vingren, JL, Fragala, MS, Hakkinen, K, and Newton, RU. Influence of exercise order in a resistance-training exercise session. *J Strength Cond Res* 20: 141–144, 2006.

26. Trebs, AA, Brandenburg, JP, and Pitney, WA. An electromyography analysis of 3 muscles surrounding the shoulder joint during the performance of a chest press exercise at several angles. *J Strength Cond Res* 24: 1925–1930, 2010.

27. Van Den Tillaar, R and Ettema, G. A comparison of muscle activity in concentric and counter movement maximum bench press. *J Hum Kinet* 38: 63–71, 2013.

28. van den Tillaar, R and Saeterbakken, AH. Fatigue effects upon sticking region and electromyography in a six-repetition maximum bench press. *J Sports Sci* 31: 1823–1830, 2013.

29. Welsch, EA, Bird, M, and Mayhew, JL. Electromyographic activity of the pectoralis major and anterior deltoid muscles during three upper-body lifts. *J Strength Cond Res* 19: 449–452, 2005.