Potential Role of Pre-Exhaustion Training in Maximizing Muscle Hypertrophy: A Review of the Literature

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ABSTRACT

THE PRE-EXHAUSTION (PE) SYSTEM IN RESISTANCE TRAINING IS LARGELY USED BY ATHLETES AND PRACTITIONERS WITH THE GOAL OF ENHANCING MUSCULAR ADAPTATIONS. PRE-EXHAUSTION CONSISTS OF PERFORMING A SINGLE-JOINT EXERCISE BEFORE A MULTIPLE-JOINT EXERCISE IN AN EFFORT TO INCREASE THE OVERLOAD (MUSCLE ACTIVATION AND/OR TRAINING VOLUME) IN A GIVEN MUSCLE. DIFFERENT PE APPROACHES HAVE BEEN INVESTIGATED IN RESEARCH; THIS REVIEW DISCUSSES THE RELEVANT LITERATURE REGARDING THE EFFICACY OF PE FOR POTENTIATING OVERLOAD AND MUSCLE HYPERTROPHY. IN GENERAL, PE DOES NOT ALTER THE NEUROMUSCULAR ACTIVITY OF THE TARGET MUSCLE IN MULTI-JOINT EXERCISE, BUT IT DOES ALLOW FOR A GREATER TRAINING VOLUME.

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INTRODUCTION

Resistance training (RT) is a modality of exercise recommended to promote muscle growth (1), and its influence on this outcome shows a dose–response relationship, at least up to a certain point (12,22–25). The effect of RT on muscle hypertrophy seems to be protocol-dependent, whereby manipulation of program variables such as volume, intensity, exercise selection, and exercise order may affect RT-induced adaptations (1,20,37). Regarding exercise order, evidence indicates that its manipulation can affect various acute and chronic RT-related outcomes (27,28). Current guidelines recommend performing multiple-joint (MJ) exercises before single-joint (SJ) exercises (1). Paradoxically, pre-exhaustion (PE) is a popular RT system used by athletes and practitioners seeking to enhance muscle hypertrophy (7,11,37).

The PE is one of the training principles described by Joe Weider (37) that involves performing an SJ exercise followed immediately by an MJ exercise for the same muscle group (e.g., performing pec deck before bench press) (37). In this system, the 2 exercises are performed in sequence with minimal rest between them (37). Another common way to perform this system is in a traditional multiple-set sequence (e.g., 3 sets of SJ before the MJ exercise) (9). The theory behind this variation is that first performing an SJ exercise fatigues the agonist in isolation, thus placing greater stress on the agonist during MJ exercise and potentiating its hypertrophy (7,21,37). Yet, another approach is to first perform an SJ exercise that works a synergist of the MJ, followed immediately with a set of the MJ movement (e.g., triceps pushdown followed by bench press). This approach has been used in scientific research and can be referred to as a reverse PE (3). The rationale for this approach is that the fatigued synergist contributes less to the subsequent MJ movement, thereby placing greater stress on the agonist

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group. Given these variations and assorted theories, the purpose of this review is to discuss the relevant literature regarding the efficacy of PE to potentiate muscle hypertrophy.

METHODS

An extensive literature search was performed using PubMed and Scielo databases. Searches were performed using the following terms in both English and Portuguese: "pre-exhaustion," "pre-activation," and "exercise order." The date of publication was not used as a criterion for inclusion and exclusion of studies. Studies were included regardless of the sample's characteristics.

RESULTS

ACUTE STUDIES

Neuromuscular activity. Several studies have investigated whether PE alters neuromuscular activity during MJ exercise. The first study on the topic was conducted by Augustsson et al. (3), who assessed the electromyographic (EMG) activity of the rectus femoris, vastus lateralis, and gluteus maximus during one set of horizontal leg press exercise with and without PE. The PE consisted of one set of a 10RM knee extension exercise. Results indicated that PE impaired rectus femoris and vastus lateralis activation during the leg press. Based on this finding, PE may be suboptimal for maximizing lower-limb activation. It is noteworthy that the inverse order was not analyzed to determine what would have happened to activation in the knee extension if the leg press was performed immediately prior. Rocha-Júnior et al. (18) examined EMG activity of the vastus lateralis during 15 repetitions of leg press 45° at 60% 1RM in 3 conditions: a control condition whereby only the leg press 45° was performed; a PE condition whereby 15 repetitions in the knee extension at 30% of 1RM was performed before the leg press 45°; and a condition where 15 repetitions in the knee extension at 60% of 1RM was performed before the leg press 45°. An increase of 67.4 and 59.5% in vastus lateralis activation was observed throughout the leg press repetitions (0–15 repetitions) after the PE with 30% and 60% of 1RM, respectively, whereas the condition without PE showed an increase of 27.6%. It should be noted that exercises were performed submaximally, with sets terminated at 15 repetitions; it remains unclear if results would have differed had sets been performed until muscle failure.

Akima et al. (2) used electromyostimulation to fatigue the quadriceps femoris in subjects performing knee extension exercise before and after stimulation. Pre-exhaustion of 1 of 4 heads of the quadriceps augmented recruitment of the 3 others when the exercise was repeated. However, this approach has limited practical application because it is impossible to stimulate only one of the vasti muscles using RT exercises.

The PE system is often used to increase pectoralis major activity during bench press performance. Gentil et al. (8) compared the neuromuscular activity of the pectoralis major, anterior deltoid, and triceps brachii during performance of the pec deck and bench press in 2 conditions: pec deck performed before the bench press (PE) and the inverse order. Results showed similar muscular activation in the pectoralis major and anterior deltoid regardless of condition, but an increase of 33% in triceps activation was noted during the MJ exercise when performed after the pec deck. Brennecke et al. (4) tested a similar experimental protocol (8), but the SJ exercise used for PE was the dumbbell chest fly. Again, PE conferred no differences in activation of either the pectoralis major or anterior deltoid in the bench press; however, triceps brachii activation increased significantly during performance (18%). Most recently, Gołas et al. (9) investigated the effects of PE on EMG amplitude in the pectoralis major during a single repetition of 95% 1RM bench press both in isolation and after performance of multiple sets of incline dumbbell fly exercise. Similar to previous findings, no significant difference in pectoralis activation was noted after PE. In total, these investigations provide evidence that PE does not increase activation of the pectoralis major when performing the bench press; on the other hand, results suggest that PE may increase the activation of a synergist muscle during MJ exercise.

Alternatively, Pirauá et al. (15) investigated muscle activation when performing the dumbbell fly (10 repetitions with 30% of 1RM) on stable (bench) and unstable (Swiss ball) surfaces before performance of the bench press. The bench press was performed until concentric failure. Results indicated significant increases in activity of the pectoralis major, anterior deltoid, triceps brachii, and anterior serratus muscles during the bench press when it was preceded by dumbbell fly, independent of surface. This finding suggests that PE may increase the activation of a target muscle during MJ when it is preceded by submaximal performance of an SJ exercise. However, considering that PE used a very light load at a low intensity of effort, it can be speculated that the enhanced activation in all muscles during the bench press may be a function of postactivation potentiation mechanisms (26) rather than prefatigue induced by PE.

Reverse PE (e.g., triceps pushdown before bench press) is postulated to increase overload in the agonists through a reduced contribution from the fatigued synergistic muscles during the MJ movement. To determine the validity of these claims, Soares et al. (30,31) investigated the neuromuscular activity of pectoralis major and triceps brachii during the triceps pushdown and bench press exercises in 2 sequences: a reverse PE whereby the triceps pushdown was followed by the bench press and a traditional sequence whereby the bench press preceded the pushdown. No significant difference was noted between conditions for both the pectoralis major and triceps brachii. Conversely, a similar balanced cross-over experimental protocol analyzing neuromuscular activity in the 10RM bench press performed before or after the triceps pushdown showed significantly greater pectoralis major activation in the reverse PE condition than the condition without reverse PE (10).

The reason for these discrepant results is unclear.

Gołas et al. (9) investigated triceps brachii and anterior deltoid EMG amplitude during the bench press, performed immediately after the lying triceps extension or front deltoid raise. Compared with the control session (without PE), EMG activity was significantly greater for the triceps brachii in its reverse PE condition (+31%), but a nonsignificant but potentially practically meaningful difference was observed for anterior deltoid after its reverse PE condition (+18%). Pectoralis major activation was not analyzed under any conditions, precluding the ability to draw inferences on the effects of reverse PE in this muscle.

Further confounding matters, Soncin et al. (32) assessed EMG activity of the pectoralis major, anterior deltoid, and triceps brachii in 6 exercises (3 sets of 8RM) using 2 opposing exercise orders: 1) bench press, chest fly, shoulder press, shoulder abduction, close grip bench press, and lying triceps extension (Sequence A); 2) or the opposite order (Sequence B), which constitutes a reverse PE. Of note, greater activation of the sternocostal head of the pectoralis major was noted in Sequence A compared with Sequence B during the chest fly. Alternatively, significantly greater EMG amplitude was noted for the anterior deltoid in Sequence B versus Sequence A during the chest fly, whereas its activation was higher during Sequence A in the lying triceps extension compared with Sequence B.

Considering the differences between PE protocols and study methodologies, it is difficult to form a definitive conclusion on the topic. That said, most studies fail to show an increase in activity of the target muscle during MJ exercise but do tend to display an increase in activation of the synergistic muscle. It is important to mention that although an association exists between neuromuscular activity and muscle growth (36), hypertrophy is a complex phenomenon (20) that can be influenced by multiple factors (34). Thus, scrutiny of longitudinal studies investigating the chronic effect of PE on hypertrophy is necessary to draw inferences as to whether any observed differences in agonist or synergist muscle activation translate into greater long-term muscle development.

Performance and training volume load. The compelling body of literature indicates a clear dose–response relationship between training volume and muscle hypertrophy (12,22–25). There also is evidence that changing the order of exercise performance alters volume load (28), whereby volume is greater when a given exercise is positioned first, regardless of whether it is MJ or SJ (28). Regarding PE, De Salles et al. (19) analyzed the effects of PE (knee extension followed by leg press) on training volume versus performing the exercises in an inverse order. Four sets of each sequence were conducted until muscular failure using an initial load of 8RM. The total number of repetitions in the session was significantly higher in the PE condition (sum of repetitions with PE = 46.9 ± 8.4 vs. sum of repetitions without PE = 38.6 ± 7.3), because of a greater number of repetitions performed in knee extension with PE (average with PE = 6.7 ± 1.3, and average without PE = 3.5 ± 1.2); the number of repetitions performed in leg press was similar between conditions.

Similarly, Faria et al. (5) and Ribeiro et al. (17) observed that execution of the PE in the triset system for both the lower-body (a) knee extension, (b) leg press, (c) squat (5); and upper-body (a) pec deck, (b) incline bench press, (c) bench press (17) resulted in a significantly greater total number of repetitions and total training volume load compared with performing the sequence in the inverse order. These results (5,17,19) indicate a more pronounced reduction in volume for traditional order (MJ after SJ), than PE (SJ after MJ), conceivably because other synergistic muscles were able to assist the MJ performance.

More recently, Vilaça-Alves et al. (35) investigated the influence of performing arm curl exercise before the lat pull-down (reverse PE) using a narrow or wide grip. Although both grip conditions resulted in a reduced volume for the lat pull-down after reverse PE, the strategy had a greater negative effect on the number of repetitions performed in the MJ exercise when using the narrow grip variation. This result is logical since the biceps brachii is worked to a greater extent in the narrow grip variation, and prefatiguing the muscle would thus limit MJ exercise performance.

Accordingly, these findings suggest a potential beneficial effect for PE from a volume-load standpoint and are in agreement with other studies showing a superiority for an SJ to MJ order in this regard (13,14,16). However, the use of reverse PE may be disadvantageous for muscular adaptations, because of reductions in training volume, mainly for the target muscle. Although research is limited on the topic, the PE system may favor performing a greater volume compared with the inverse order (5,8,19), whereas reverse PE seems to impair total training volume, especially for the target muscle (30,31,35).

LONGITUDINAL STUDIES

To the best of our knowledge, only one study (6) has investigated the chronic effects of PE as originally proposed (7,37). Fisher et al. (6) randomized a sample of 39 participants (male = 9 and female = 30) with at least 6-month RT experience into 1 of 3 groups: a PE group that performed exercises in the following order: (a) pec fly, (b) chest press, (c) leg extension, (d) leg press, (e) pull-over, and (f) lat pull-down, with minimal rest (≤5 seconds) between SJ and MJ exercises (e.g., peck-fly and chest press) and 120 seconds rest after finishing each MJ exercise; a group that performed the same exercises in the same order but with a rest of 1 minute between exercises (PE-1 min); or a control group (CON) that performed the same exercises but began with the MJ exercises first and rested for 1 minute between exercises. Training was performed twice a week for 12 weeks; participants performed 1 set of no more than 12 repetitions per exercise until failure. Measures of lean mass were assessed by air displacement plethysmography (ADP). Results revealed no significant changes for any group in lean mass, making it difficult to draw any conclusion on the effect of PE in muscle hypertrophy. The lack of changes in lean mass can be related to the following factors: (a) use of a single set per exercise protocol for trained individuals, which is in opposition to generally accepted recommendations (1,12,22–25), and/or (b) the use of ADP as a measurement instrument, a method that has limited ability to assess hypertrophic changes.

Two other studies have endeavored to investigate the effects of exercise order on hypertrophy, with sequencing in the nontraditional training condition similar to a reverse PE (29,33). Simão et al. (29) and Spineti et al. (33) compared performing MJ exercise followed by SJ exercise (bench press, lat pulldown, triceps extension, and biceps curl) to the inverse order. Results showed no significant difference between groups for both triceps brachii (MJ-SJ = +15%, SJ-MJ = +12%) and biceps brachii muscle volume (MJ-SJ = +10%, SJ-MJ = +13%). Alternatively, Simão et al. (29) observed that, for the triceps brachii, only the SJ-MJ condition significantly increased muscle thickness from pre-training to post-training (MJ-SJ = 0.0%, SJ-MJ = +8%). However, although biceps brachii muscle thickness was similar between conditions, only the MJ-SJ group showed a significant difference to a nonexercising CON at post-training (MJ-SJ = +6%, SJ-MJ = +4%).

The conflicting results of the limited longitudinal data on PE prevent the ability to draw strong inferences as to whether the strategy enhances muscle hypertrophy. Furthermore, direct site-specific measures of muscle hypertrophy on the topic have only been obtained in the upper limbs; no studies have endeavored to investigate changes in the trunk or lower body. Further research is needed to fill in these gaps in the literature.

PRACTICAL APPLICATIONS

Based on available literature, we can conclude that PE does not augment neuromuscular activity of the target muscle in MJ exercise, but it can enhance activity of the synergistic muscle. From a volume-load standpoint, PE favors a greater training volume load, mainly due the increase in the number of repetitions performed in the SJ exercise, but it may reduce the volume load in the MJ. The paucity of longitudinal data prevents the ability to draw conclusions as to the direct effects of PE on muscle hypertrophy.

It can be concluded that PE may be a viable strategy to use during a hypertrophic training mesocycle. Specifically, PE can help to increase training volume, which has been shown to be a primary driver of hypertrophy (24). It has been hypothesized that progressively increasing RT volumes over a period of several months may elicit a supercompensation of muscle proteins to maximize hypertrophic adaptations (22). The use of PE could conceivably be used during the high-volume block to facilitate the maintenance of increased volume. Alternatively, reverse PE would seemingly be contraindicated in this regard because it seems to negatively influence total training volume. The current literature is insufficient to determine whether PE promotes any additional anabolic effects from a mechanistic standpoint over and above traditional RT, so any use for this purpose remains speculative.

Future longitudinal studies using PE should be performed to fill existing gaps in the literature and thus provide greater insight into the potential implications for its practical use. The use of site-specific measurement techniques (e.g., ultrasound, magnetic resonance image, and computed tomography) would be helpful for tracking subtle changes in muscle hypertrophy. Moreover, studies should endeavor to analyze hypertrophic changes of the agonist muscle in MJ exercise (e.g., pectoralis major, latissimus dorsi, and quadriceps), as opposed to just the synergists (e.g., biceps brachii and triceps brachii).

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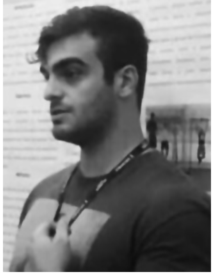

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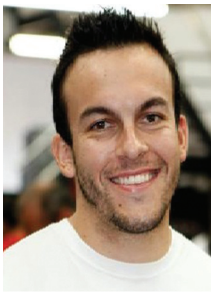

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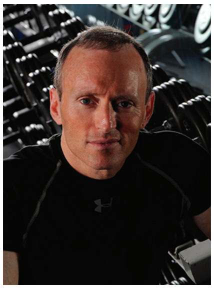

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