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THE EFFECTS OF MUSCLE ACTIONS UPON STRENGTH GAINS

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ABSTRACT

Purpose. The purpose of this study was to compare the effects of concentric with eccentric muscle actions on strength gains. **Methods.** Forty-two untrained men were randomly divided into three groups: the concentric experimental (CE), the eccentric experimental (EE) and a control (C). The CE group performed only concentric muscle actions at 80% of one repetition maximum (1 RM) and the EE group performed only eccentric muscle actions at 120% of 1 RM. Both groups trained by performing three sets of 10–12 repetitions for eight weeks of biceps curl (BC) and bench press (BP) exercises. The C group did not engage in any type of training. **Results.** Analyses performed within the CE group found that there were significant improvements in muscle strength in the eighth week of BP (Δ% = 26.9%, p = 0.01) and in the fourth and eighth week of BC (Δ% = 22.1%, p = 0.00 and Δ% = 32.1%, p = 0.00, respectively). Analyses of the EE group found that there were significant improvements in muscle strength in the fourth and eighth week of BP (Δ% = 13.7%, p = 0.00 and Δ% = 28.4%, p = 0.00, respectively). Between the two groups (CE versus EE), comparisons showed that the CE group performed significantly better than the EE group in the fourth and eighth week of BC (p = 0.00 and p = 0.00, respectively). **Conclusions.** These findings indicate that those who do not train should perform concentric muscle actions in the first 8 weeks of training in order to generate accelerated strength improvement.

Key words: training, exercise, concentric, eccentric, repetition maximum

Introduction

Eccentric muscle actions occur when muscles elongate under tension. Conversely, concentric muscle actions occur when muscles, except for tendon connective tissue [1], undergo shortening while under tension. Acute effects, such as greater tension per motor unit, less energy expenditure, lower electromyographic (EMG) activity, a reduction in the range of joint motion, increased swelling and muscle damage, and delayed onset muscle soreness are well documented and more commonly associated with activities involving eccentric muscle actions than those involving concentric muscle actions [2–5]. However, the more lasting effects, such as increased muscle strength, have yet to be clarified.

A combination of concentric and eccentric muscle actions (the traditional method) is commonly used in resistance training for muscle strength development. Hilliard-Robertson et al. [6] reported that resistance training composed of both eccentric and concentric muscle actions, which largely emphasizes eccentric muscle actions appears to give greater strength gains than when concentric muscle actions are used alone. Corroborating this finding, the American College of Sports Medicine (ACSM) [7] recommends the use of both muscle actions as a combined strategy for increasing maximum strength, power, hypertrophy and muscle endurance. In addition, Dudley et al. [8] show that the omission of eccentric muscle actions compromises strength increase, probably due to the fact that the necessary intensity is not optimal. Furthermore, others studies have also observed that dynamic muscle strength improvements are greatest when eccentric muscle actions are included in training programs [9–11]. Thus, it seems that eccentric muscle actions, when combined with concentric or isolated actions, are indispensable for enhanced muscle strength development.

However, others studies have reported conflicting results, showing no significant difference between the acquired strength gains after performing these two types of muscle actions [12, 13]. Furthermore, it is important to mention another study that compared the strength development of two groups, one of a traditional concentric/eccentric group and the other a solely concentric group. No significant differences were found between the two groups [14], showing that the

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exclusion of eccentric muscle actions does not compromise increased muscle strength.

Given that such isolated concentric or eccentric muscle actions are not commonly used in resistance training of untrained individuals and the lack of certainty regarding the strength gains from concentric or eccentric muscle actions, it is important that their more prolonged effects, such as increased muscle strength, be better understood.

Thus, the purpose of this study was to compare the effects of concentric with eccentric muscle actions on strength gains in untrained men who performed BC and BP exercises over a period of eight weeks. It was hypothesized that after eight weeks of resistance training of the untrained men, concentric muscle actions may provide significant and accelerated increases in muscle strength when compared to eccentric actions.

Material and methods

The study sample was composed of 42 healthy, untrained men who were randomly divided into three groups: the concentric experimental group (CE, n = 14, age = 26.6 ± 2.1 years, height = 176 ± 14 cm, weight = 78 ± 3.9 kg, % body fat = 12.25 ± 2.97%), which used only concentric muscle actions during resistance training; the eccentric experimental group (EE, n = 14, age = 28.2 ± 2.8 years, height = 175 ± 14 cm, weight = 76 ± 4.7 kg, % body fat 13.91 ± 3.33%), which used only eccentric muscle actions and a control group (C, n = 14, age = 27.2 ± 3.3 years, height = 176 ± 14 cm, weight = 77 ± 4.1 kg, % body fat 13.34 ± 3.22%), which did not engage in any type of training.

The following inclusion criteria for the subjects were established: a) no participation in regular physical activity for six months previous to this study; b) a body mass index (BMI) ≤ 25 $\text{Kg} \cdot \text{m}^{-2}$ to avoid poor fitness levels that could compromise movement execution; c) negative responses on the Physical Activity Readiness Questionnaire (PAR-Q) [15].

The exclusion criteria were: a) use of medication that could influence functional response behavior; b) bone, muscle or joint problems that could limit the execution of the proposed exercises; c) changes in sleep patterns and daily diet.

The subjects signed an informed consent form according to the Declaration of Helsinki and the study was approved by the governing Research Ethics Committee (protocol number 0046/2007).

Pre-training (PRE) data were collected on five different days over a period of 10 days. On the first day, all individuals were subjected to medical history examinations and the anthropometric measurements were taken of body mass, using an electronic scale (Filizola, Brazil), height with a stadiometer (Sanny, Brazil), and percentage body fat using a skinfold caliper (AXF 356, Cescorf, Brazil) as according to the three-side skinfolds protocol [16]. Furthermore, the subjects were familiarized with the BP and BC exercises using concentric muscle actions in the CE group and eccentric muscle actions in the EE group. On the second and third day, each 48 hours apart, all of the subjects underwent two more familiarization sessions for the same exercises.

On the fourth day, 48 hours after the third familiarization session, all subjects were submitted to 1 RM testing of both BP and BC. 1 RM was defined as the maximum amount of weight that can be lifted one time with proper technique through a full range of motion [17]. For the BP, the subjects were positioned on the bench with both feet flat on the floor, starting the movement with elbows fully extended and the shoulders in a horizontal flexion. They performed an elbow flexion until the bar touched the hand of one researcher, experienced in resistance training, who was positioned beside the subject (see Fig. 1), with the subject then returning to the starting position. For the BC, the subjects sat on a bench, initiating the movement with their forearms touching the trestle positioned in front of the bench (see Fig. 2), performing a full elbow flexion and then returning to the initial position.

Figure 1. The position used when performing the BP

Figure 2. The position used when performing BC

On the fifth day, 48 hours after determining 1 RM, the subjects were re-tested to obtain load reproducibility. The highest of the two values found on the two test days was considered the subject's 1 RM, with a negligible difference of 5%. If the difference was greater than 5%, the test was performed again to define the ideal load. Subjects were not allowed to engage in any exercise between the test sessions in order to avoid any interference with the results. Moreover, the 1 RM tests and re-tests were performed once again at the end of the fourth and eighth week.

To minimize possible errors with the 1 RM test and re-testing, the following strategies as prescribed by Simão et al. [18] were implemented: a) all of the subjects received standardized instruction on data assessment and the exercise technique before testing; b) the exercise technique was monitored and corrected as needed; c) all subjects received verbal encouragement during testing; d) and the weight of all the weight plates and bars used was determined with a precision scale. The rest interval was about five minutes between each exercise attempt and 10 minutes between the different exercises. The maximum number of attempts for each exercise was three. If a subject did not achieve 1 RM in these three attempts, they were asked to perform another 1 RM test session.

On the sixth day, 48 to 72 hours after the 1 RM testing process, the CE and EE groups were submitted to the first of their 16 training sessions, which occurred twice a week over a period of eight weeks. Before initiating the exercises, the subjects performed a warm-up consisting of 10 repetitions at 40% of 1 RM for the CE group and 80% of 1 RM for the EE group for both BP and BC. The CE group's warm-up involved only concentric muscle actions while only eccentric muscle actions for the EE group. A two-minute rest interval was allowed between the warm-up and the assigned training exercise.

To establish the training load of the subjects in the EE group, 20% was added to their 1 RM load [12]. This addition was necessary so that during the eccentric muscle actions the subjects could not resist or avoid stretching. Conversely, 20% was deducted from the 1 RM load of the CE subjects. This deduction was necessary so that during the concentric muscle actions the subjects could perform the number of repetitions required during training, as it would not be possible perform 10–12 repetitions of 100% of 1 RM.

After the warm-up session, the subjects of the CE group performed three sets of 10–12 repetitions with concentric muscle actions at 80% of 1 RM while those in the EE group performed three sets of 10–12 repetitions with eccentric muscle actions at 120% of 1 RM, for both exercises. When the subjects were able to perform 12 repetitions without muscle fatigue (failure) during the three sets of each exercise with the prescribed load, the training load was then increased by 10% of 1 RM.

The rest interval between the sets and exercises was three minutes [19, 20]. The velocity of movement was controlled with a digital stopwatch (HS-30W, Casio, Japan), with three seconds given for each muscle action (concentric or eccentric) totaling 30 seconds under tension for each set of 10 repetitions. The subjects returned to the initial position as soon as possible after each muscle action without being subjected to overload. Two experienced resistance training researchers ensured that the correct technique was followed and the prescribed training load was met.

During training, concentric muscle actions were performed as follows: for the BP, one of the researchers placed the bar into the hands of the subject while it was being held by the other researcher who was positioned beside the subject (initial position). A concentric muscle action was performed and the bar was removed from the subject hands when his elbows were completely extended (final position). For the BC, the bar was handed to the subject whose forearms rested on a pad found in front of the bench (initial position). A concentric muscle action was performed and the bar was removed from the subject's hands when his elbows were fully flexed (final position).

During training, eccentric muscle actions were performed as follows: for the BP, a researcher placed the bar into the hands of the subject while his elbows were completely extended (initial position). An eccentric muscle action was performed and the bar was removed from the subjects hands when it touched the hand of the researcher who was positioned beside the subject (final position). For the BC, the bar was handed to the subject when his elbows were fully flexed (initial position). An eccentric muscle action was performed and the bar was removed from the subject's hands when his forearms touched the pad (final position).

The data collected are presented as mean ± SD. The Levene test was used to verify the homogeneity of variance. Once homogeneity was confirmed, a mixed model ANOVA (the group [CE, EE, C] x testing time [PRE, fourth, eighth week]) was conducted to compare the results within and across the groups for both exercises. The Tukey post-hoc test was used to identify significant difference [21]. Statistical software was used for all analyses (Statsoft Version 5.5, Statsoft, USA) and a level of 0.05 was used to determine significance.

Results

Comparisons performed within the CE group showed significant improvements in muscle strength in the eighth week of performing the BP exercise ($\Delta\%$ = 26.9%, p = 0.01) and in the fourth and eighth week of performing the BC exercise ($\Delta\%$ = 22.1%, p = 0.00 and $\Delta\%$ = 32.1%, p = 0.00, respectively) when compared to the PRE data. Comparisons made within the EE group revealed significant improvements in muscle

Table 1. 1 RM tests at PRE, the fourth and then eighth week of resistance training

	1 RM bench press (kg)			1 RM biceps curl (kg)		
Groups	PRE	4 weeks	8 weeks	PRE	4 weeks	8 weeks
CE (*n* = 14)	65.7 (15.0)	75.7 (10.8)†	80.5 (4.01)*†	32.8 (5.01)	39.4 (3.37)*†‡	42.5 (3.18)*†‡
EE (*n* = 14)	63.8 (1.65)	72.0 (4.43)*	80.4 (4.01)*†	30.2 (6.51)	32.0 (6.57)	36.0 (7.69)
C (*n* = 14)	66.8 (7.47)	67.0 (7.30)	69.4 (7.93)	31.7 (2.81)	32.0 (3.33)	33.4 (2.98)

Data are expressed as mean (SD).
1 RM = One repetition maximum
PRE = Pretraining
Kg = Kilogram
CE = Concentric Experimental Group
EE = Eccentric Experimental Group
C = Control Group

* significant difference ($p < 0.05$) from PRE data
† significant difference ($p < 0.05$) from the C group
‡ significant difference ($p < 0.05$) from the EE group

strength in the fourth and eighth week of the BP exercise (Δ% = 13.7%, $p = 0.00$ and Δ% = 28.4%, $p = 0.00$, respectively) when compared to the PRE data. As expected, no significant differences were demonstrated within the C group. Across-group comparisons revealed significant improvements in muscle strength in the CE group in the fourth and eighth week compared with the fourth and eighth week in the C group for both exercises: for BP ($p = 0.01$ and $p = 0.00$, respectively), and for BC ($p = 0.00$ and $p = 0.00$, respectively). When comparing the EE and C groups, only in the eighth week of BP were significant improvements found in muscle strength in the EE group ($p = 0.00$). In comparisons between the CE and EE groups, the strength gain of the CE group was significantly higher than in the EE group in the fourth and eighth week of BC ($p = 0.00$ and $p = 0.00$, respectively). However, the difference was not significant in the fourth and eighth week of BP (see Tab. 1).

Discussion

It was hypothesized that in the eight weeks of training, concentric muscle actions could result in significant and accelerated strength gains than when compared to eccentric muscle actions in the group of untrained individuals. To test this hypothesis, the participants of this study were trained and tested in two exercises. In the first exercise (BC), the CE group performed better than the EE group, while the strength gain was similar in the second exercise (BP). As such, the results of the across-group comparisons (CE vs. EE) confirm the stated hypothesis.

However, the confirmation of the stated hypothesis is in direct contrast to previous studies [11, 22, 23]. Kaminski et al. [11] compared strength gains between eccentric and concentric muscle actions involving the hamstring muscles of trained subjects. They reported that the group performing eccentric muscle actions improved by 29%, while the group using concentric muscle actions showed only 19% improvement. In another study, Hollander et al. [22] demonstrated that eccentric muscle actions resulted in greater strength gains than concentric muscle actions in six exercises tested in men with resistance training experience. Furthermore, Vikne et al. [23] compared the effects of concentric and eccentric muscle actions on muscle strength of trained subjects. They also concluded that eccentric muscle actions led to greater strength increases than concentric muscle actions (with eccentric 26% > concentric 9%).

The discrepancy between, for example, the BC results in this study and those obtained by Kaminski et al. [11], Hollander et al. [22] and Vikne et al. [23] may be due to the fact that they studied trained subjects. In this study only untrained subjects were analyzed, and it seems that neural factors account for the larger initial strength increase in the first weeks of training [24]. In addition, Fang et al. [25] revealed that detailed comparisons of EMG signals suggest that eccentric muscle actions require a significantly longer time for early preparation and a significantly greater magnitude of cortical activity for later movement execution. Furthermore, during eccentric muscle actions, fewer motors units are recruited than in concentric actions [26]. This suggests less total muscle activity which in turn suggests lower neural adaptation. Higbie et al. [27] concluded that total muscle activity (EMG activity) during eccentric muscle actions was less than in concentric muscle actions before training. The similar result between EMG activity in pre- and post-training during concentric and eccentric muscle actions suggests that the neural adaptation of eccentric muscle actions was still less even after 10 weeks of training.

Therefore, it seems that in the beginning of a training period for untrained individuals, eccentric muscle actions show greater neural inhibition (i.e., reduced neuromuscular activation), but would later decrease with continued training [28]. Thus, it is likely that the longer preparation time needed for eccentric muscle actions [25], associated with greater neural inhibition [27], delayed strength evolution thereby contributing to the lower strength gains observed in the EE group after BC.

By contrast, the strength gain obtained in BP by the CE and EE groups was similar. However, this team suggests that the BP exercise was favored by the isometric contraction of the pectoralis muscle, a fact observed during the BC exercises performed by the EE group. Babault et al. [29] reported that the neural drive (the number of motor units or their discharge rate) during eccentric muscle actions is lower than during isometric contraction. This suggests that isometric contractions, unlike eccentric muscle actions, show lower neural inhibition and higher muscle activity. Therefore, the impossibility of excluding the isometric contractions and their high muscle activity avoided delaying the strength gain obtained by the EE group in BP, and contributed to the similar findings obtained by the CE group in the same exercise. However, the results of the abovementioned studies [27, 28] suggest that if this experiment had been carried out for more than eight weeks (i.e.; 10, 12, 14, or more weeks), the results would have been different, that is, the EE group would likely have performed significantly better than CE group in both exercises (BC and BP).

The weakness of this study may be the lack of specificity between the muscle actions used and the tests performed (1 RM). Higbie et al. [27] analyzed the effects of eccentric versus concentric unilateral knee extension training on strength gains in women. After 10 weeks, they concluded that the concentric muscle action group performed better in concentric specifics tests, while the group using eccentric muscle actions exhibited enhanced performance in specific eccentric tests.

Conclusion

This study makes an important contribution to the available literature in this subject. After eight weeks of training, concentric muscle actions resulted in significant and accelerated strength gains in untrained men when compared to eccentric muscle actions. Therefore, since the original stated hypothesis was confirmed, it can be concluded that concentric muscle actions should be used in the first eight weeks of training of untrained individuals to generate accelerated strength improvement. By contrast, eccentric muscle actions should be excluded to avoid any possible delayed effects. However, new studies are needed to evaluate if only single-joint or only multi-joint exercises show the same response to different types of muscle actions. Tests must also be applied singly (more specific) to better elucidate the existing discrepancies. Moreover, longer training periods (more than eight weeks) should also be used to confirm the delayed effects of isolated eccentric muscle actions in the first eight weeks of training of untrained individuals.

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