Effects of Accentuated Eccentric Resistance Training on Concentric Knee Extensor Strength

Michael P. Godard, John W. Wygand, Ralph N. Carpinelli, Steve Catalano, and Robert M. Otto
Dept. of Health, Physical Education & Human Performance Studies, Adelphi University, Garden City, New York 11530.

Reference Data

ABSTRACT
This study tested the hypothesis that concentric resistance exercise along with an accentuated eccentric load would elicit greater increases in concentric strength than training with a similar amount of resistance for concentric and nonaccentuated eccentric muscle actions. Pre- and posttraining concentric one repetition max (1-RM) of the left knee extensors was used to measure strength in 28 untrained young men and women. Resistance for concentric and eccentric muscle actions was a constant external torque initially set at 80% of the concentric 1-RM for subjects in the Con/Ecc group. Resistance for the eccentric component of the Con/Ecc+ group was 40% greater than their concentric resistance. Both groups trained with one set of 8-12 unilateral repetitions (3 sec concentric, 3 sec eccentric) to muscular fatigue twice a week for 10 weeks on a Cybex 6000 dynamometer. There were significant increases in concentric knee extensor torque in both groups, with no significant difference between groups. The results suggest there is no significant further enhancement of maximal concentric torque from training with an accentuated eccentric resistance in previously untrained persons.

Key Words: isotonic, torque, specificity

Introduction
One of the primary goals of most resistance training programs is to enhance muscular strength as safely and efficiently as possible. The evidence strongly suggests that strength training protocols that employ a combination of concentric and eccentric muscle actions are superior to those using only concentric muscle actions to enhance muscular strength and hypertrophy (2, 3, 5, 7, 10). Although it is well known that muscles can generate a greater torque during an eccentric muscle action than during a concentric muscle action, the physiological mechanisms for this difference are unknown (6). It has been speculated that capitalizing on this greater torque-producing potential and increasing the resistance for the eccentric component of combined concentric/eccentric resistance exercise training will produce greater increases in concentric strength and muscular hypertrophy (7). However, there is no scientific evidence to support the superiority of this type of accentuated eccentric resistance training.

The purpose of this investigation was to compare the effects of 10 weeks of strength training in a group using the same resistance for unilateral knee extensor concentric and eccentric muscle actions (Con/Ecc group) to a group using an accentuated eccentric resistance (Con/Ecc+ group) for each repetition.

Methods
Twenty-eight physically active men (n = 16) and women (n = 12) who were not currently performing resistance exercise training volunteered to participate and signed an informed consent. Subject characteristics are shown in Table 1. Each subject underwent a familiarization trial before the initial concentric one repetition maximum (1-RM) testing of the left knee extensors on a Cybex 6000 dynamometer, which was programmed in the isotonic powered mode at 30° sec⁻¹. Knee extension was measured with the subjects seated (90° hip flexion) while applying force to a cushioned lever arm positioned anteriorly on the ankle. Restraints were applied on the thigh, leg (proximal to the talus), pelvis, and shoulders. Range of motion was individually determined with full knee extension limited at 180°.

Table 1
Pretraining Physical Characteristics of 16 Male and 12 Female Participants

| Group   | n  | M ±SD | M ±SD | M ±SD | M ±SD
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age (yrs)</td>
<td>Body mass (kg)</td>
<td>Thigh girth (cm)</td>
<td>1-RM (N m)</td>
<td></td>
</tr>
<tr>
<td>Con/Ecc+</td>
<td>9</td>
<td>22.0</td>
<td>3.0</td>
<td>69.3</td>
<td>16.4</td>
</tr>
<tr>
<td>Con/Ecc</td>
<td>9</td>
<td>21.1</td>
<td>1.5</td>
<td>71.4</td>
<td>17.2</td>
</tr>
<tr>
<td>Control</td>
<td>10</td>
<td>24.0</td>
<td>4.8</td>
<td>65.0</td>
<td>14.3</td>
</tr>
</tbody>
</table>
Based on their concentric 1-RM (Newton · meters), subjects were placed in rank order, matched, and randomly assigned to one of three groups: Con/Ecc (n = 9), Con/Ecc+ (n = 9), or Control (n = 10). All girth measurements were assessed by the same investigator using a tension-regulated tape measure. The average of triplicate measurements to the nearest 0.1 cm at the largest horizontal circumference of the left thigh was recorded.

Training for both groups consisted of one set of 8 to 12 unilateral repetitions twice a week for 10 weeks on the Cybex 6000. Each repetition was approximately 6 seconds (3 sec concentric, 3 sec eccentric). Speed of movement was controlled by the participants with the help of a Cybex monitor set at 30° · sec⁻¹ and a metronome set at 60 bpm. Resistance for concentric and eccentric muscle actions, which can be programmed separately in the isometric powered mode, was a constant external torque. It was initially set at 80% of the concentric 1-RM for the Con/Ecc group. The Con/Ecc+ group followed the same protocol except that the resistance for the eccentric component was 40% greater than their concentric resistance.

During each session the subjects were instructed by the same investigator to maintain proper exercise form and speed of movement. The set of repetitions was terminated when the subject was either unable to move the resistance throughout the full range of motion or unable to maintain the speed of movement. When a subject completed 12 repetitions, the resistance (concentric and eccentric) was increased approximately 5% for the next session.

A one-way ANOVA was applied to the pretraining data (concentric knee extensor torque, left thigh girth, body mass, age) to confirm similarity among the 3 groups. A repeated measures ANOVA was used to determine significant differences (pre- and posttraining) within the training and control groups for 3 dependent variables: 1-RM, thigh girth, and body mass. Scheffé post hoc analysis was performed when the one-way ANOVA revealed significant differences among groups during posttraining analysis. Statistical significance was established at p < 0.05.

Results

All subjects completed the 10 weeks of training with nearly 100% compliance (2 subjects each missed 1 training session). None reported any injuries from training. Two subjects from each training group reported some mild delayed onset muscle soreness during the first week of training, but none expressed any major discomfort or limitation. Results showed significant increases in concentric knee extensor torque (Figure 1) from 85.8 ± 23.3 to 167.4 ± 35.5 N · m in the Con/Ecc group, and from 88.0 ± 20.9 to 170.4 ± 32.4 N · m in the Con/Ecc+ group. Left thigh girth significantly increased from 51.2 ± 4.5 to 54.4 ± 4.6 cm in the Con/Ecc group, and from
49.9 ± 5.0 to 52.4 ± 5.2 cm in the Con/Ecc+ group (Figure 2). There was no significant difference between the training groups for either the increases in strength or thigh girth. There was no significant change in torque (89.2 ± 27.5 and 94.9 ± 28.5 N·m) or girth (48.2 ± 4.1 and 48.5 ± 4.0 cm) pre- to posttraining in the control group. During the course of the study none of the groups had any significant change in body mass.

Discussion

The increases in strength for the Con/Ecc and Con/Ecc+ groups (101% and 106%, respectively) in this study were considerably greater than the 7 to 71% increases reported in a review of 12 studies on lower extremity strength training (7). Training protocols for those studies typically employed multiple sets (3 to 5) at a frequency of 3 times a week for 8 to 24 weeks. The authors of the review stated that the range of increases in strength was probably due to the variability of the participants’ pretraining status.

Cureton and colleagues (4) reported the results of strength training 3 times a week for 16 weeks in previously untrained men and women, who increased their concentric knee extensor strength by ~29% and ~34%, respectively. Perhaps the high intensity/low volume training in our investigation, which was a product of only one set of 8 to 12 repetitions twice a week, provided not only an effective overload but also sufficient time to recuperate and respond to the exercise stimulus.

The significant hypertrophy of the left thigh in both training groups suggests that morphological as well as neurological factors contributed to the increases in strength. Adaptations in maximal neural activation, which result from optimal activation of the prime movers and synergists with concomitant inhibition of the antagonists, can be learning-induced or attributed to the training effect per se (15). Neural adaptation may be responsible for most of the strength gains during the early conditioning of an untrained person (9). Hypertrophic adaptations may contribute to strength gains after about 8 weeks of conditioning (12). The relatively small but statistically significant increases in thigh girth for both training groups (5% and 6%), compared with the 101% and 106% increases in concentric torque, appear to support this scenario of primarily neural adaptation rather than hypertrophic adaptation.

The accentuated eccentric resistance (+40%) did not result in a significantly greater increase in concentric strength. Perhaps because both groups exercised the knee extensors to the point of concentric muscular fatigue, the 40% accentuated eccentric resistance did not elicit greater motor unit recruitment than what was required for the concentric movement. It is not known whether the eccentric 1-RM was enhanced to a greater degree in the Con/Ecc+ group because, based on pilot studies, we felt that testing the maximal eccentric torque in the isotonic powered mode might subject healthy untrained participants to relatively high and potentially dangerous torques.

The results of this study are in agreement with those of Ben-Sira et al. (1). Participants in a conventional bilateral concentric/eccentric training group (Conv) performed 3 sets of 10 reps with both limbs simultaneously, using 65% of their bilateral 1-RM twice a week for 8 weeks. Training in the supramaximal group (SmET) was similar to that in the Conv group except that the SmET group performed the eccentric phase with only one limb at a time, alternating contralateral limbs. Thus each limb performed 5 eccentric muscle actions during each set with twice the unilateral concentric resistance.

Both groups in the Ben-Sira et al. study (1) had significant increases in concentric strength (~18% for Conv, ~23% for SmET), with no significant difference between groups. The degree of effort may have varied considerably among the participants; they all performed 10 reps with the same percentage of their 1-RM (65%), and the resistance was increased 5% for all participants every 2 weeks. In our investigation, all participants performed each set until they could no longer complete their range of motion at 30° a second. When an individual completed 12 reps, increments in resistance were assigned for the next session. Therefore, each set of repetitions resulted in a maximal effort; this may account for the fivefold strength gains compared with those reported by Ben-Sira et al. for untrained subjects (1).

In their review of lower body muscle action specificity, Morrissey et al. (13) noted that either concentric or eccentric training can improve concentric and eccentric lower body strength. Studies showed that after concentric training, the increases in concentric strength were not significantly greater than those for eccentric strength (13). Petersen et al. (14) reported increases in isokinetic average and peak torques of 11% and 12% concentrically, and 18% and 21% eccentrically, as a result of concentric knee extensor training. They concluded there was no evidence to support a muscle action specificity principle.

Enoka (6) has speculated that the nervous system may not be capable of commanding a muscle to activate eccentrically. Whether or not the length of an activated muscle changes depends on the magnitude of the torque generated by the resistance relative to the torque exerted by the muscle. Perhaps exercising a specific muscle to the point of concentric fatigue is sufficient to elicit similar increases in concentric and eccentric strength, regardless of the action of the muscle at the time of the stimulus.

Hortobagyi et al. (11) recently demonstrated the possibility of muscle action modality specificity. After performing 4 to 6 sets of 8 to 12 reps 3 times a week for 12 weeks, previously untrained men, who performed maximal isokinetic eccentric exercise for the knee extensors, increased their maximal isokinetic eccentric torque 116% and their maximal isokinetic concentric
torque 5%. Men who trained with maximal isokinetic concentric exercise increased their maximal concentric torque 53% and their eccentric torque 10%. Hortobagyi et al. concluded that eccentric training elicited greater increases in the specific muscle action (eccentric) than concentric training.

Significant strength increases in specific tests (e.g., maximal eccentric torque) would be indicative of muscle action specificity. However, the physiological and practical significance of a preferential (specific) increase in eccentric torque is unknown. Although there is some support for specificity of muscle action strength increases, there is no evidence that it exists when both concentric and eccentric muscle actions are employed.

Practical Applications

We recognize the limitations of not testing maximal eccentric torque and the crucial information that could have been accrued. More study is needed to determine whether a greater eccentric component would enhance either maximal concentric or eccentric torque in trained participants, who may be at a lower risk of injury from maximal eccentric testing. Gibala et al. (8) recently reported that myofibrillar disruption was significantly greater following eccentric muscle actions (~82%) compared with concentric muscle actions (~33%), while using the same resistance for either concentric or eccentric muscle actions. It is not known what degree of disruption would result from an accentuated eccentric resistance, so its application to rehabilitation is questionable at this time.

It was not the purpose of this study, nor were we equipped, to measure specific neuromuscular aspects of strength. The attempt was to determine whether the relatively common practice of overloading the eccentric component of a repetition would enhance concentric strength to a significantly greater degree than conventional concentric and eccentric exercise with similar resistances. In conclusion, although eccentric muscle actions have been shown to be a vital component for maximal strength and hypertrophy in men and women, our results suggest there is no significant further benefit to training with an accentuated eccentric resistance (+40%) in previously untrained persons. One set twice a week of high intensity exercise (100% concentric effort on the last repetition) using the same resistance for concentric and eccentric muscle actions was shown to be just as effective in producing increases in concentric strength and thigh girth.

References