

Can eccentric exercise of the lower limb be made more efficiently, a pilot study

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1. Abstract

Background: Eccentric Exercise has been shown to be more effective in building muscle and healing damaged tissue than concentric or isometric exercise. It has also been shown to be effective in increasing motor control. But the duration of therapeutic exercise in physical therapy is limited by insurance to 30-60 minutes a day.

Objectives: Four standard therapy eccentric exercises of the lower limbs were compared (toe raise, ball exercise, side lying eccentric exercise and incline board exercise) to a trainer called the BTE Eccentron to see if the efficiency of exercise could be increased using one exercise session to meet or beat the four individual exercises.

Subjects and Methods: The study examined eight randomly selected participants with no known medical conditions (neurological or orthopedic) that would preclude their participation (age=24.1+/-2.1 years height=168.9+/-6.4 cm BMI=23.2+/-3.2). EMG was used to assess muscle recruitment in each exercise. The muscles studied were the gastrocnemius, hamstring, hip adductors, and quadriceps muscles.

Results: Muscle use on the eccentron was almost double that of the other exercises. Thus, making

therapy more efficient. One single exercise bout showed more muscle activation during eccentric exercise than the other four exercises, with an average muscle use almost 4 times higher on the eccentron.

Conclusion: The Eccentron offers a considerable advantage for clinical treatment making exercise and neuromuscular training more efficient.

2. Key words: Exercise, Eccentric Exercise, EMG, Muscle Recruitment.

3. Introduction

Eccentric exercise involves allowing the muscle to lengthen while active force is generated [1,2]. There are several benefits gained with eccentric exercise that are not found with concentric or isometric exercise. Eccentric loading favors an increase of type II fiber cross-sectional area (CSA) during high exercise intensities [1,3]. Multiple studies have shown significant increases in the distribution of type II fibers in skeletal muscle in response to eccentric resistance training [1,3]. Secondly, since eccentric contractions require less energy and can produce more

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force, it is possible to train against greater loads [3]. Third, eccentric training has a larger potential for increasing the expression of collagen-inducing growth factors in muscle compared to concentric training. Recent papers point to an increase in neuromuscular control caused by eccentric exercise and as a benefit of that neuromuscular control, a reduced injury risk from falling [4,5]. Most therapy has concentrated on increasing muscle strength as a means of preventing injury [6-8]. The high costs of injuries such as knee injuries make it important to adjust therapy to maximize the chance of injuries [9]. An often-overlooked fact is that motor patterns that increase injury risk are often seen in many patients [7,10,11]. These strategies include poor planning for movement and altered postural control. Recent evidence clearly shows that eccentric exercise can improve neuromuscular control. The evidence comes from the EMG (electromyogram) activity during eccentric exercise in relation to motor planning and control. The surface EMG is an interference pattern that reflects the action potentials in the underlying muscle [12-17]. Many attempts have been made to use either the amplitude or frequency components of the surface EMG as a means of assessing the tension developed in muscle or the degree of fatigue in muscle during either isometric or dynamic exercise [18-23]. Concerning the amplitude of the EMG, some investigators point to a linear relationship between the amplitude of the EMG and the tension in muscle during brief isometric contractions [19,24,25]. Other investigators report non-linear relationships between the surface EMG and the tension exerted by muscle for muscles like the biceps [26,27]. While some of the variation has been attributed to the type of electrode (needle or surface) or the size or position of the electrodes [28], much of the difference in various studies is unexplained.

4. Study Rationale and objectives

While there have been numerous review articles on the benefits of eccentric exercise, the problem

remains that individual exercises on the lower limb take time to accomplish and with an ever-shrinking insurance environment, the exercises are impractical to accomplish. However, a trainer, the Eccentron, exercises both legs with eccentric exercise at the same time. The purpose of this study was to determine muscle activity during specific lower limb eccentric exercises through the EMG activity and compare it to the eccentric to see if therapy can be shortened and have similar if not better results.

5. Subjects

The study used eight randomly selected participants with no known medical complications. Participants were between 22 and 27 years old. The age, heights and weights of the group are listed in Table 1.

Table 1: Demographics of the subjects (means+/_standard deviation)

	Age (years)	Height (cm)	Weight (Kg)	BM I
mean	24.1	168.9	66.5	23.2
SD	2.1	6.4	12.5	3.2

Volunteers who had physical injuries or known medical conditions that impaired the cardiovascular system or neuromuscular system including diabetes were excluded. Typical medical conditions included stroke, heart disease, pulmonary impairments such as emphysema or Asma. Additionally, bone disorders that weakened bone such as osteoporosis were excluded. Exclusion also included all neuropathies and myopathies. Participation in the study was voluntary, and only those who granted their consent were recruited. Persons who had musculoskeletal injuries within the last one year were excluded from the research. The volunteers were informed about the research process including its purpose and duration. They could participate in regular physical activity but not a training program on a team or gym. Participants were informed that they could withdraw from the research at any time if they so desired. The researchers acquired approval from the Touro University Institutional review board.

6. Methods

Eccentron- The study used the BTE eccentron™ which is a computerized eccentric muscle exerciser. During operation, the machine generates a force that pushes the legs of the user who in turn counters by applying a resistance force. This method allows the lower limb muscles to lengthen when under the opposing force hence experiencing eccentric contractions. First, the subjects exercised for 3 minutes to determine their maximum capacity for exercise. Next, after a 5-minute rest, they exercised at 100% of their capacity for 2 minutes.

Other Eccentric Exercises. The following four exercises were used;

Exercise one: Calf muscles eccentric loading- toe raise

In this exercise the subject stood on a step with their heels hanging over the side of the step. The patient was asked to raise on their toes and then slowly lower their heel past the step to the count of 4 going down. The subject then performed a toe raise ready for the next repetition. The exercise was performed four times. This exercise was designed to develop eccentric loading to the calf muscles, the gastrocnemius and the soleus.

Exercise two: Eccentric loading to the hamstrings- ball exercise

In this exercise the subject lied on a mat on the floor. Their feet (heels) were on an exercise ball and their knees were extended. The exercise was performed by lifting their hips off the floor and bringing their knees to their chest. The subject then slowly extended their legs holding their hips off the floor, to the count of 4. This process was repeated four times. Thus, performing an eccentric loading to the hamstrings.

Exercise three: eccentric load to the adductors of the hip- side lying lift

In this exercise the subject was side lying on a mat on the floor. Their top leg was resting on a platform that was 0.66 meter over the other foot. The subject was then asked to raise the bottom foot off the floor

with their knee straight. After reaching the undersurface of the platform, the subject was then asked to slow lower the leg to the count of 4. Four repetitions were performed.

Exercise four: eccentric loading of the quadriceps muscle group-decline board.

In this exercise the subject was standing on one leg, on a decline board with an angle of 30 degrees. The subject was asked to slowly bend their knee, to the count of 4, until they could no longer see their toes. They were then instructed to extend their knee. After they performed four repetitions the subject switched legs and performed the same exercise on the opposite side.

7. EMG

To determine muscle activity, the electromyogram was recorded. EMG was recorded by two electrodes and a reference electrode placed above the active muscle. The relation between tension in muscle and surface EMG amplitude is linear for these four muscles [17,22,23,29,30-33]. Thus, the amplitude of the surface electromyogram can be used effectively as a measure of the activity of the underlying muscle by simply normalizing the EMG compared to a maximal effort. Muscle activity was assessed by first measuring the maximum EMG of the muscle during a maximal effort (3 seconds) and then, during any exercise, assessing the percent of maximum EMG to calculate the percent of muscle activity. A biopotential amplifier conditioned the electrical output from the muscle with a gain of 2000 and frequency response, which was flat from DC to 1000 Hz (EMG 100C amplifier, Biopac Inc., Goleta, CA). The amplified EMG was digitized with a 24-bit analog to digital converter and sampled at a frequency of 2000 samples/sec (MP150, Biopac Inc., Goleta, CA). The software to analyze the EMG was the Acknowledge 3.8.1 package (Biopac Inc., Goleta, CA).

8. Procedures

All subjects participated in all exercises. The order

of the exercises was selected at random for the four exercises and eccentric exercises. EMG was recorded during the exercise from the gastrocnemius, hamstring, quadriceps, and hip adductors as described under methods. The electrodes were placed on the skin over the belly and distal to the belly of each of the muscles in line with the muscle fibers. The skin was shaved and cleaned using isopropyl alcohol. The electrodes were placed apart by 20 mm. Before the exercise, a maximum effort was recorded from each of the muscles as described under methods.

9. Data Analysis

Descriptive data for both the dependent measures and the demographic variables were calculated, and tests of homogeneity of variance and normality were used for the statistical tests assumptions. T-tests and ANOVA were used to compare the study groups' baseline characteristics.

10. Results

The results of the measurements of muscle activity are shown in Figures 1-4.

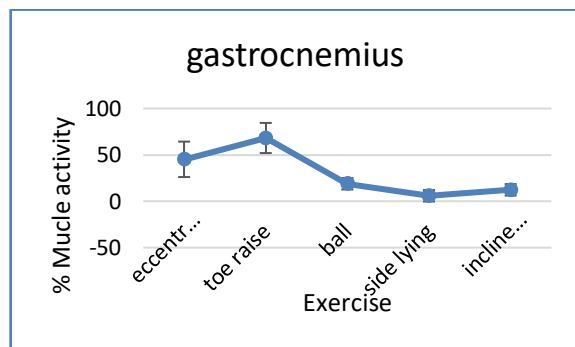


Figure 1: Illustrated here is the average muscle activity of the gastrocnemius muscles in 8 subjects +/- the standard deviation for activity on the eccentric exerciser, the toe raise, the exercise ball, side lying and on the incline board. Data has been normalized as a percent of the maximum EMG during a maximal effort with that muscle group.

As shown in Figure 1, the muscle activity in the medial gastrocnemius muscle was significantly higher for the eccentric and the toe raises than the other three exercises (ANOVA $p < 0.01$). There was no significant difference in the EMG activity (muscle activity) for the ball exercise, side lying exercise or the incline board (ANOVA $p = .42$).

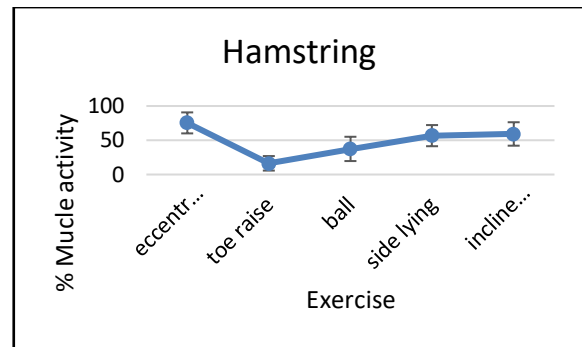


Figure 2: Illustrated here is the average muscle activity of the hamstring muscles in 8 subjects +/- the standard deviation for activity on the eccentric exerciser, the toe raise, the exercise ball, side lying and on the incline board. Data has been normalized as a percent of the maximum EMG during a maximal effort with that muscle group.

The results for the hamstring muscles are shown in Figure 2. As can be seen here, the muscle activity for the hamstring muscles during the eccentric exercise was significantly higher than the other four exercises (ANOVA $p < 0.01$). The average muscle activity was 75% of the maximum strength of these muscles. However, there were no difference in hamstring muscle activity for the side lying or the incline board exercises ($P = 0.33$) which were different than the ball exercise, the toe raises and eccentric. The hamstring activity during the toe raises was significantly less than the other four exercises ($p < 0.01$ ANOVA).

The results of the muscle activity of the quadriceps group are shown in Figure 3. There was no difference in activity between the eccentric and incline board for this muscle group ($p > 0.05$). But compared to the

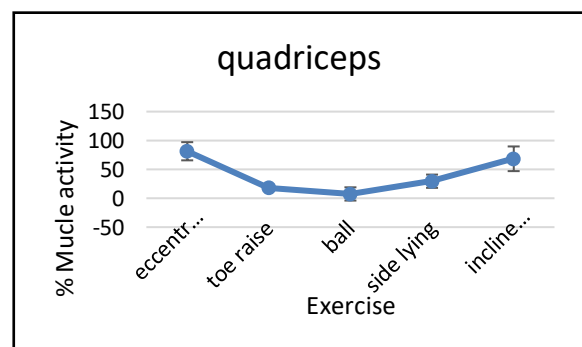


Figure 3: Illustrated here is the average muscle activity of the quadriceps muscles in 8 subjects +/- the standard deviation for activity on the eccentric exerciser, the toe raise, the exercise ball, side lying and on the incline board.

Data has been normalized as a percent of the maximum EMG during a maximal effort with that muscle group. other three exercises, muscle activity was significantly higher for these two exercises (ANOVA $p < 0.01$). The ball exercise had significantly less activity than the toe raises and the side lying exercise ($p < 0.05$). For the eccentric, muscle activity was over 80% of muscle strength for the quadriceps.

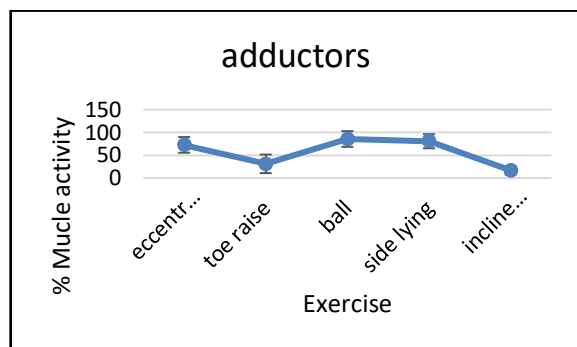


Figure 4: Illustrated here is the average muscle activity of the hip adductor muscles in 8 subjects +/- the standard deviation for activity on the eccentric exerciser, the toe raise, the exercise ball, side lying and on the incline board. Data has been normalized as a percent of the maximum EMG during a maximal effort with that muscle group.

The muscle activity of the hip adductors was significantly lower for toe raises and the incline board than the other three exercises (ANOVA $p < 0.01$). The muscle activity for these two exercises was not different from each other ($p > 0.05$). Likewise, for the eccentric, the ball exercise and the side lying exercise the muscle activity of the hip adductors was not different from each other. ($p > 0.05$) Looking at all five exercises, as shown in Table 2, the average muscle activity for the four muscles groups is shown for each exercise.

Table 2: The average muscle activity for all subjects and averaged across the four muscle groups for each exercise. This table indicates each point represents the average of 32 measurements showing the % of muscle activity for the exercise.

Exercise	Average Muscle Activity (%Max)
Eccentron	60.4
Toe raise	33.5
Ball	37.3
Side lying	43.2
Incline board	39.2

As shown in Table 2, the average muscle activity as a percent of the muscle's maximum strength for all four muscle groups averaged together was nearly double on the eccentric as for the other four exercises. While the other four exercises were not significantly different from each other, the eccentric was significantly higher than the other four exercises (ANOVA $p < 0.01$). Of interest is the fact that the other four exercises were on one limb at a time. The eccentric exercised both limbs and therefore was even more effective, with muscle activity almost 4 times as high.

11. Discussion

The purpose of this study was to evaluate the optimal exercise that could be used for patients undergoing an eccentric exercise program on the lower limbs. The advantage of Eccentric exercise is that it can increase strength and heal damaged tissue. An additional benefit is neuromuscular re-education. The evidence clearly shows that many of the factors that lead to falls are linked to poor neuromuscular control [11,34,35]. While strength alone does not predict balance disorders, neuromuscular control does predict instability [36]. Eccentric exercise increases neuromuscular control [4]. Thus, the more efficient eccentric exercise would benefit older patients with poor motor control. Due to the limitations on time for therapy imposed by the government and insurance carriers (usually 1-2 15 minute modalities per day), the aim of this study was to see if a single eccentric exercise machine could accomplish training of both legs at once at the same level or better than 4 individual exercises used in physical therapy.

Based on the amplitude of the EMG, a measurement can be made about the intensity of exercise and how each exercise affects each of the four main muscle groups in the legs, the gastrocnemius, quadriceps, hamstring and hip adductors [17,23,33]. Here, the muscle activity was measured as a percent of the EMG during a brief maximal effort. This method provides a reliable measure of the percent of active

muscle during each exercise examined here. For the purpose of developing exercise programs, the EMG signal amplitude can provide a general guideline as to the difficulty of the exercise. Loads of 45% to 50% of the maximum EMG amplitude for a given muscle has been shown to increase strength in previously untrained individuals [31,37].

This study supports the feasibility of the BTE Eccentron™ for exercise in healthy individuals. Even examining a single leg and measuring muscle activity on the four muscle groups examined here, the average muscle activity using the eccentron was nearly double the activity of the same muscle in the four individual exercises. However, since both legs were exercised together on the eccentron, the muscle activity was equal to 8, 15-minute modalities to exercise both legs. This exerciser then accomplished what the study wanted to examine, the feasibility of using a single exerciser for 15 minutes to exercise both legs. However, further inquiry is required to investigate the translatability of findings to a larger population, and older adults. Further, while motor control has been examined with eccentric exercise, the effects of the eccentron on lower body motor control have not been examined and should be done. Also, the exercise protocol was focused on the lower limbs and, as such, results cannot be presumed to be identical for the upper limb or torso musculature. Finally, only four traditional eccentric exercises were considered; due to possible variation in exercises prescribed by physicians and therapists, it is possible that alternative exercises may be more effective at muscle activation than those noted in this study. To further understand the potential use of the BTE Eccentron™ for strength development and injury rehabilitation, more research is warranted.

12. Conclusion

The BTE Eccentron™ is a resistance strength trainer that has been touted to enable automatic eccentric loading to reduce lower limb injury risk, enhance recovery, and improve strength adaptations. This

analysis was performed to assess the feasibility of incorporating the BTE Eccentron™ into training and recovery programs. We found that the BTE Eccentron™ generates greater muscle activation compared to the traditional eccentric exercises prescribed by practitioners.

Conflict of Interest

None of the authors have any conflicts of interest and no competing interest.

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