

Muscle Use during Isometric muscle co-contraction compared to Abdominal Crunches and A Commercial Multi Gym Exerciser

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Abstract

Isometric exercise has been shown to increase metabolism in muscle. By contracting agonist / antagonist muscle pairs, appreciable muscle activity can be achieved. An advantage of isometric exercise is that no exercise equipment is needed; people can exercise at home on their own. In the present investigation 16 subjects were examined during an isometric co contraction exercise video compared to situps and 8 weight lifting exercises to assess how much work was done on each. The results of the experiments showed that the video worked out all 10 muscle groups whereas the other exercises targeted specific muscle groups. The video was equivalent to doing continuous situps for 8 minutes, lifting 20 lbs with a chest press, 10 lbs with a biceps curl, 10 lbs with a triceps curl, 30 lbs with a lats pull down, 60 lbs of back extension, 30 lbs of abdominal flexion, 40 lbs of leg extension or 50 lbs of a leg curl for 8 minutes.

Keywords: exercise, exertion, isometrics

1 Introduction

Muller, almost 75 years ago, published a paper showing increased isometric strength could be achieved with repeated bouts of isometric exercise[1]. They suggested that if strength of greater than 1/3 of the maximum strength was exerted each day, muscle atrophy in bed rest could be eliminated as well as

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training of individuals not in bed. Since then numerous studies have been conducted on isometric strength and endurance and isometric training [2-11]. Isometric strength or maximum voluntary contraction (MVC) is the maximum strength that can be achieved by muscle [10, 12-15]. It is not even increased with electrical stimulation if the subject is well motivated. When exercise is expressed as a percent of this strength, endurance for exercise is exponentially increased as the workload is reduced [16, 17]. Working at loads over 70 % of maximum in the upper body muscle can cause fatigue whereas in the legs, workloads over 15% MVC can cause fatigue[4, 18].

Repeated bouts of isometric exercise involving co-contraction of muscle have been used for training[19]. Such bouts are especially good for training since they involve 2 opposing muscle groups exercising simultaneously. Isometric strength training is specific to the muscle groups that are exercising[20]. The advantage though, is that it can be accomplished at home, in bed, in airplanes or anywhere. It can even be done in movie theaters while watching movies. It is probably one of the easiest exercise modes to accomplish.

Thus a good isometric training exercise bout would need to involve many different parts of the body. In the present investigation, isometric exercise was accomplished in an 8 minutes video. Different exercises were used for the upper and lower body to achieve a thorough workout. To compare this workout to other exercise, it was compared with commercial weight lifting equipment. To understand the level of work achieved in the various types of exercise, the electromyogram was used to assess the force generated by the muscles during the exercise. The EMG amplitude is proportional to the exertion level in the muscle[10-15]. The relationship between emg amplitude and muscle strength is linear[21-26]. Therefore, by obtaining the maximum emg amplitude during an MVC, the exertional level can be determined [27, 28]. The emg then was used here for this purpose.

2 Subjects

The subjects in these studies were 16 females. The sample size was sufficient to achieve statistical significance by power analysis. Medical screening was conducted prior to participation in the study to assure subjects were free of cardiovascular, neurological, or orthopedic injuries. The general characteristics of the subjects are listed in Table 1. All protocols and procedures were approved by the Solutions IRB and all subjects have signed a statement of informed consent.

Table 1- General Characteristics of the subjects

	age (years)	height(cm)	weight(kg)
mean	30.6	168.2	76.0
sd	7.4	6.9	27.6

3 Methods

Video Exercise

An 8 minute exercise video was used for these studies. It consisted of a series of isometric co-contractions of the lower and upper body muscles. There were 7 videos on the tape produced by Savvier LP (Carlsbad, California). An initial study was done examining EMG on all 7 videos and a video was selected that was in the middle between the hardest and easiest video for the larger experiment.

Determination of muscle activity – To determine muscle activity, the electromyogram was used. EMG was recorded by two electrodes and a ground electrode placed above the active muscle [21, 24-26, 28, 29]. The relation between tension in muscle and surface EMG amplitude is linear [26, 28]. Thus, the amplitude of the surface electromyogram can be used effectively as a measure of activity of the underlying muscle by simply normalizing the EMG in terms of a maximal effort. Muscle activity was therefore assessed by first measuring the maximum EMG of the muscle during a maximal effort and then, during any exercise, assessing the percent of maximum EMG to calculate the percent of muscle activity [24, 26]. The electrical output from the muscle was amplified with a biopotential amplifier with a gain of 2000 and frequency response, which was flat from DC to 1000 Hz (EMG 100C amplifier, Biopac Inc., Goletta, CA). The amplified EMG was digitized with a 24-bit analog to digital converter and sampled at a frequency of 1000 samples/sec (MP150, Biopac Inc., Goletta, CA). The software to analyze the EMG was the Acknowledge 4.3.1 package (BioPac Inc., Goletta, CA).

Commercial Weight Lifting Equipment – A Body-Solid G10b gym system (San Diego, California.) was used for these studies. The exercises used were the chest press, biceps curl, triceps curl, lat pull down, abdominal extension, abdominal flexion, leg extension, leg curl, and leg press (Figure 1).

Abdominal floor crunches- This exercise was done supine, with the feet on the floor, heels 12-18 inches apart, and the knees flexed. The abdominals were flexed to lift the shoulders and head off the floor to an angle of 30 degrees. The arms were crossed on the chest.



Figure 1: weight lifting system

4 Procedures

Three series of exercises were performed. Prior to any measurements, a maximal isometric contraction was exerted to measure the maximum EMG during a 100% effort. This was used to normalize EMG muscle activity during exercise to assess the use of the muscles.

Series 1- video exercises

Series 2- This series involved abdominal floor crunches. EMG was measured as described above.

Series 3- Lastly, subjects used commercial weightlifting equipment and contracted each individual muscle group against 3 different loads as shown in Table 2 below. EMG was measured during these contractions. Subjects were asked to exercise at a normal rate for weight lifting for a period of at least 45 seconds at each load and, from these data, a 25 second average of muscle use was computed. The timing was 2 seconds agonist muscle activity, 2 seconds antagonist and 2 seconds of rest in each repeat.

Table 2: Exercise and workloads

Exercise	Trial 1 Weight (lbs, Kg)	Trial 2 Weight (lbs, Kg)	Trial 3 Weight (lbs, Kg)
Chest Press	10 lbs, 4.5 kg	20 lbs, 9.0 kg	30 lbs, 13.5 kg
Biceps Curl	10 lbs, 4.5 kg	20 lbs, 9.0 kg	30 lbs, 13.5 kg
Triceps Curl	10 lbs, 4.5 kg	20 lbs, 9.0 kg	30 lbs, 13.5 kg
Lat Pull Down	10 lbs, 4.5 kg	20 lbs, 9.0 kg	30 lbs, 13.5 kg
back Extension	20 lbs, 9.1 kg	40 lbs, 18.1 kg	60 lbs, 27.2 kg
Abdominal Flexion	30 lbs, 9.1 kg	40 lbs, 18.1 kg	60 lbs, 27.2 kg
Leg Extension	30 lbs, 9.1 kg	40 lbs, 18.1 kg	60 lbs, 27.2 kg
Leg Curl	20 lbs, 9.1 kg	40 lbs, 18.1 kg	60 lbs, 27.2 kg
Leg Press	40 lbs, 18.1 kg	60 lbs, 27.2 kg	80 lbs, 54.5 kg

5 Data Analysis

Data analysis included the calculation of means, standard deviations and T tests as well as Analysis of variance. The level of significance was $p < 0.05$.

6 Results

Series 1, video

As can be seen in figure 2, the muscle activity varied greatly during the 8 minute workout. For example examining the 10 muscles recorded here at minutes 2,3 and 8, the video alternated and used different muscles in the upper and lower body.

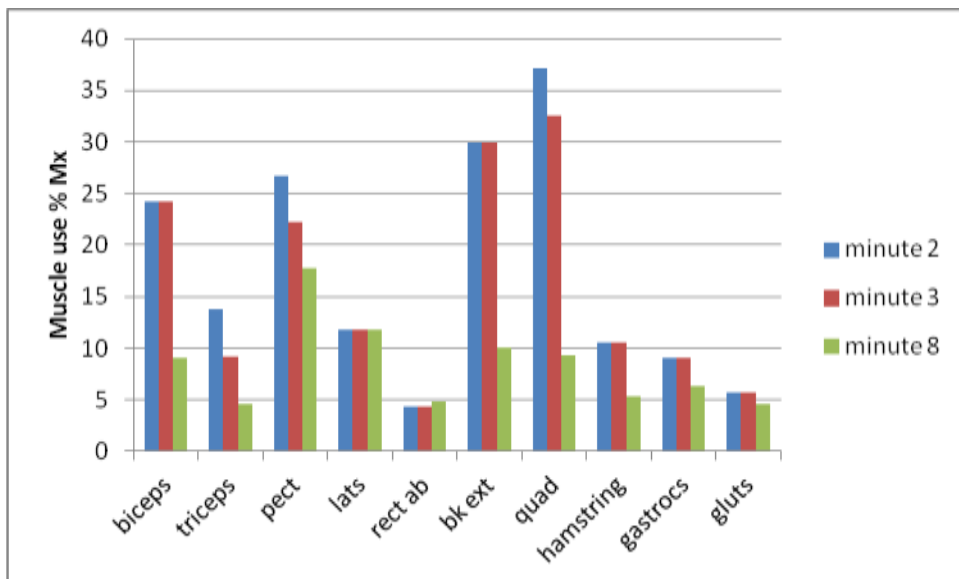


Figure 2: average muscle activity in minute 2,3 and 8 of video 1

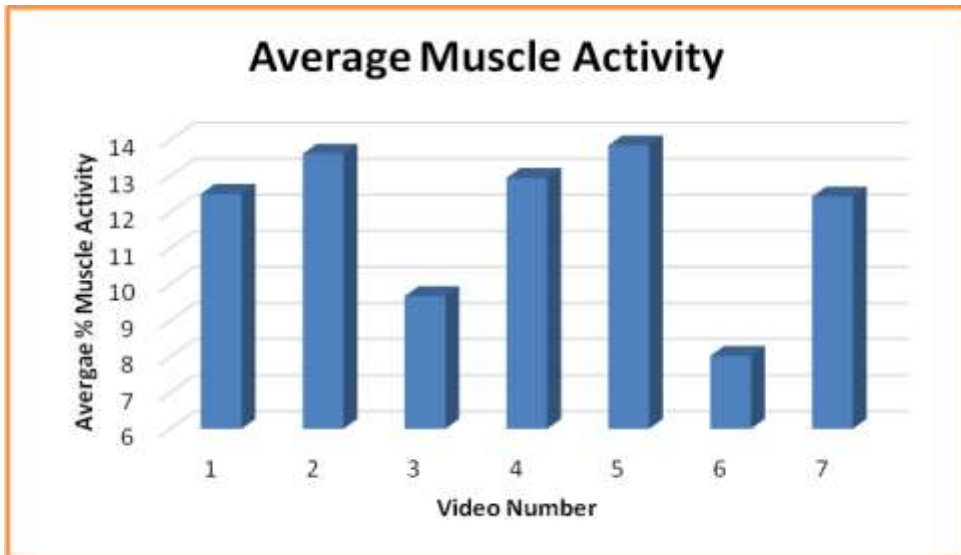


Figure 3: average muscle activity of all 10 muscles examined here during the 8 minute video.

Thus, when averaging all the muscles together, as shown in Figure 3, the average muscle activity for all muscles ranged from 8.02 % to a high of 13.8% of muscle activity over 8 minutes. The video chosen was an average of the high and low, video #1 which was 12% muscle activity. The video exercised all 10 muscle groups that were examined as shown in Figure 4.

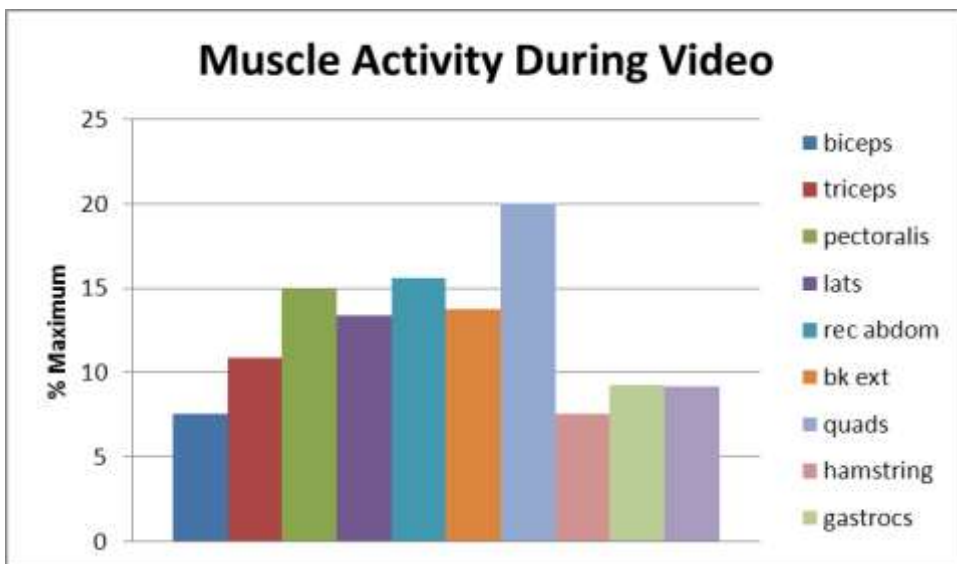


Figure 4: specific muscle activity during the 8 minute video as the average of 16 subjects.

For the 8 minutes of workout, the work accomplished (muscle use x duration) was 195.1+/-65 units.

Series 2- Abdominal crunches

The muscle use during the abdominal crunches is in Figure 5.

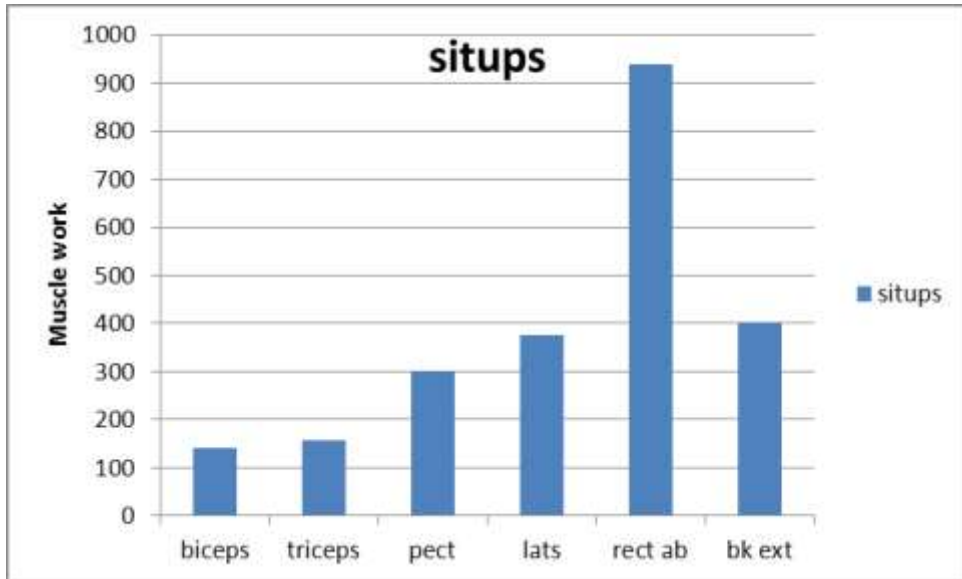


Figure 5- average work during sit-ups in 16 subjects.

As shown in Figure 5, the sit-ups used a variety of muscles and averaged 24.1+/-14.4% of the 6 muscles used here; other muscles were inactive. For the full 10 muscles, the average activity was 14.4 % during the 8 minute workout or a workload of 115.95.

Series 3- Commercial Weight Lifting Equipment

The muscle use and work for the commercial weight lifting equipment is shown as below.

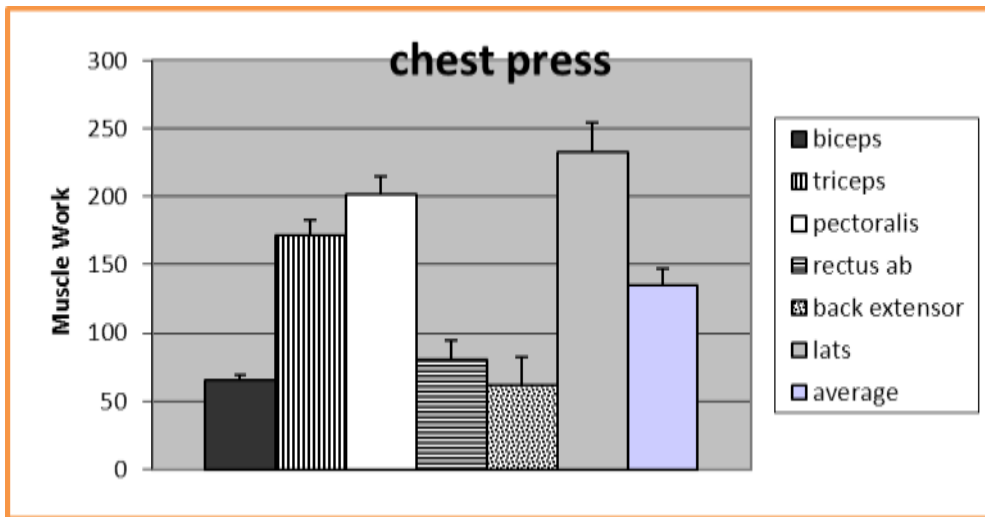


Figure 6: chest press lightest workload power on 16 subjects.

As shown in Figure 6, a typical upper body exercise was the chest press. Illustrated is the chest press for the lightest workload. The muscle use in the upper body muscles is shown on the y axis.

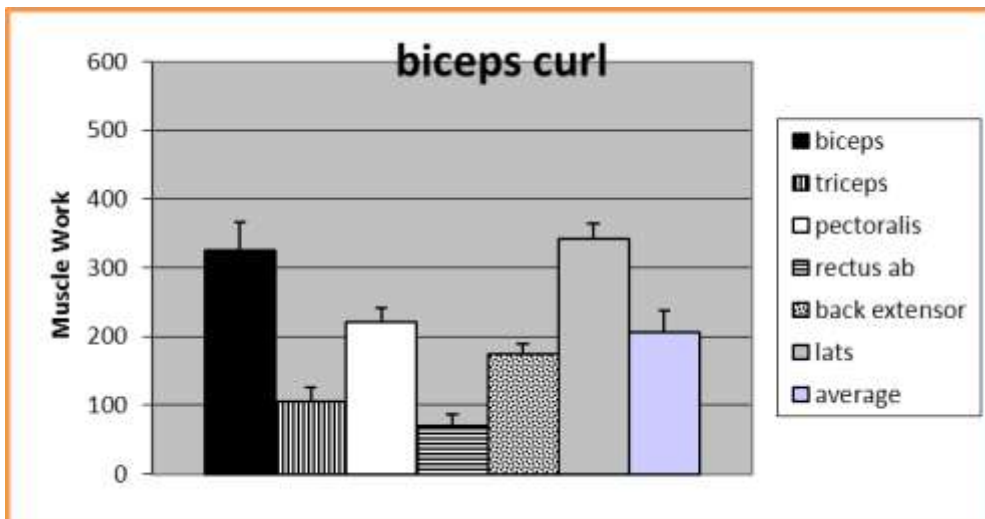


Figure 7- biceps curl lightest workload work on 16 subjects.

In a similar manner, the biceps curl muscle activity for the lightest workload is illustrated for all 16 subjects in Figure 6. As might be expected, of the 10 muscles examined, the major appreciable activity was in these 6 muscles with the biceps showing the greatest activity.

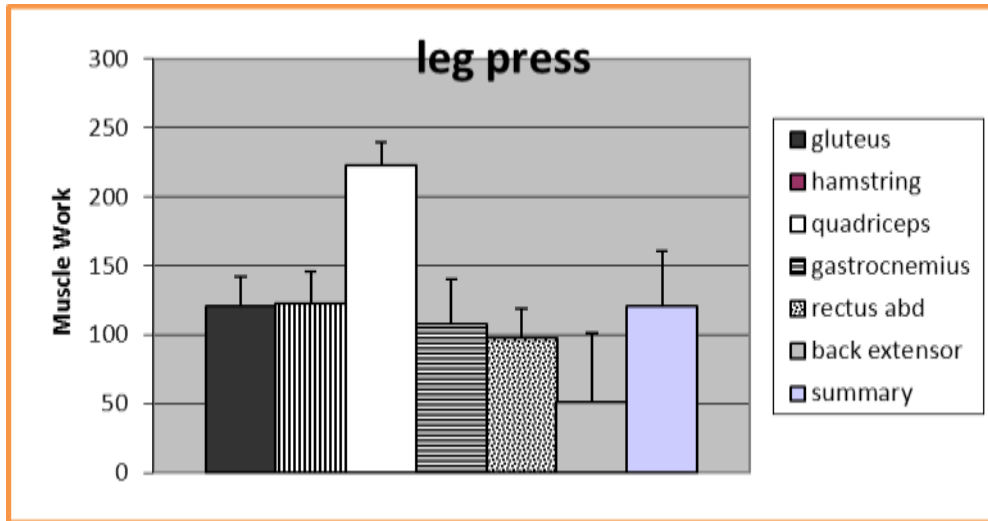


Figure 8: leg press lightest workload power on 16 subjects.

But for all the exercises on the commercial weight lifting equipment, there were 3 workloads examined, a low, medium and high load. Thus for the 3 loads examined on the leg press as an example, as workload increased, (Figures 8,9 and 10 so did muscle activity. As workloads became heavier, there was also substitution of the muscles so that other muscles were recruited to help the major muscles accomplishing the exercise.

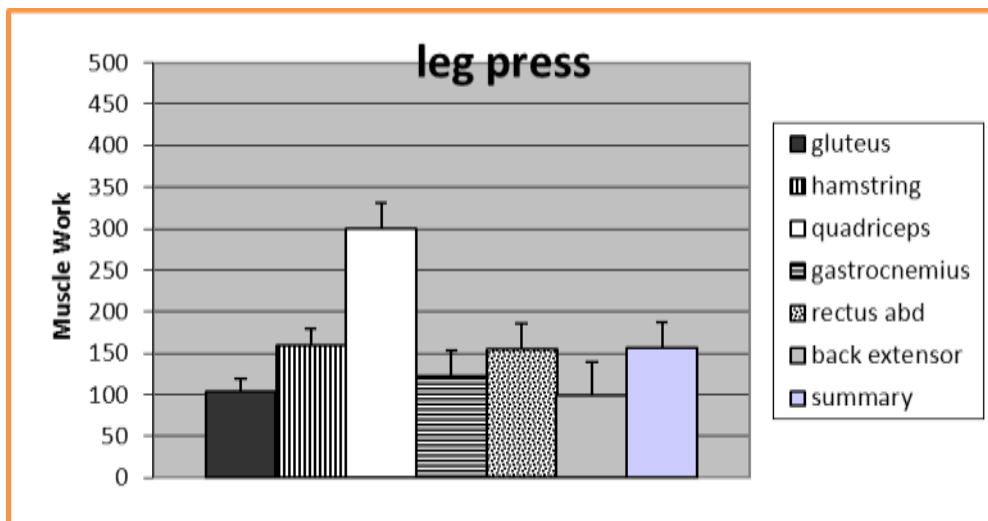


Figure 9: leg press middle workload power on 16 subjects.

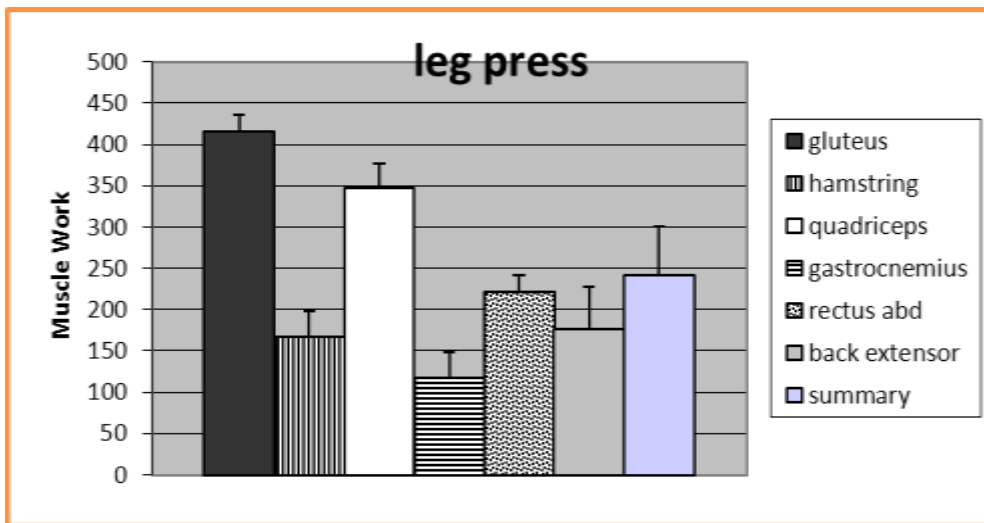


Figure 10: leg press high workload power on 16 subjects.

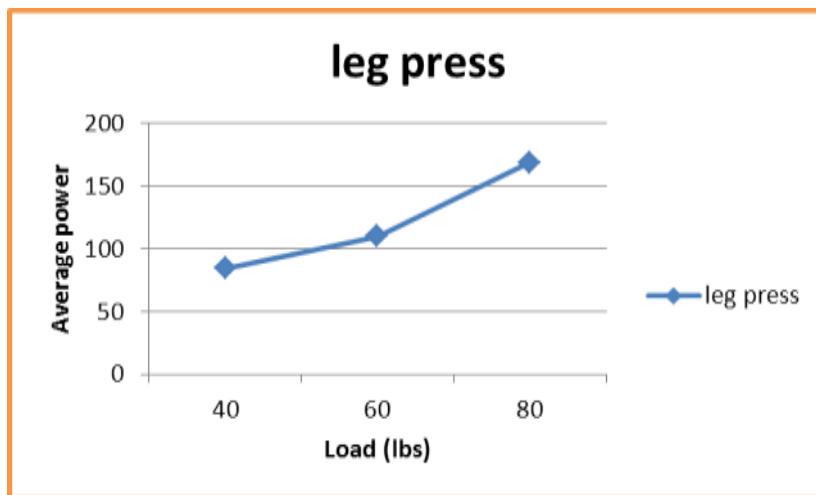


Figure 11- leg press for 3 workloads as the average power on 16 subjects.

Once the average muscle use was derived for each workload and each exercise, the total power used over an 8 minute period was calculated as shown in Figure 10 for the leg press. As seen here, from this graph, as load increased so did work. From each of these graphs Table 2 was calculated. This table shows, for each exercise, what the equivalent load would be to work at the same level as the video.

Table 2- Table of equivalent work to the 8 minute video.
As shown in Table 2, the 8 minute video was equivalent, for example to

	video	equivalent work	
video		////	
situps		situp	
chest press		20lbs	
biceps curl		10lbs	
triceps curl		10lbs	
lat pull down		30 lbs	
back extension		60 lbs	
abdominal extension	flexion	30 lbs	
leg extension		40 lbs	
leg curl		50 lbs	

7 Discussion

It is well accepted that exercise, especially a mixed exercise regime is a good way to increase overall fitness[3]. But many exercise regimes require large, heavy and expensive gym based equipment. Other portable equipment can also be bulky. Therefore, by using isometric co contraction of muscle there can be appreciable contraction of muscle and powerful contraction to build muscle and increase metabolism[4]. Isometric exercise has also been shown to be a good mode to build muscle strength[4].

In the present investigation, in spite of the fact that no exercise equipment was used, there was significant muscle use during the 8 minute video. The average level of muscle activity was 12% for the muscles studied. Since 30% muscle activity causes rapid fatigue and 15% causes some fatigue, this exercise could be continued for appreciable time with no fatigue[4, 18]. With weight lifting, the spikes in muscle use were much more extreme than the video and as such most subjects were very fatigued by the highest work load.

Thus, the exercise video was a very good training workout. This was not the hardest of the videos and was not the lightest. By alternating the videos each day, a workout of different areas of the body can be achieved. In all cases, even for the hardest video, the workload was not overly fatiguing. This is important for older individuals since high isometric workloads can cause blood pressure to be elevated. By keeping these workloads low, the video is a much safer exercise technique than is found in weight training where the heart is overloaded even in younger individuals.

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