ELECTROMYOGRAPHICAL COMPARISON OF CONCENTRIC AND ECCENTRIC PHASE DURING SELECTED ABDOMINAL EXERCISES

Dr. Hussain I., Sharma K., Ahsan M., & Ansari

Abstract

The purpose of this study was to compare the electromyographical (EMG) activity / amplitude (force) variation of contractions (Concentric and Eccentric) during sit-up exercises on rectus abdominis. The amplitudes of contraction of all the quadrants during three different sit up were recorded. Ten male subjects selected for the experiment were of All India Intervarsity level players from Aligarh Muslim University, Aligarh. Their mean age, height and weight was 20.6 years, 167.4 cm and 62.6kg respectively. The Student Physiograph (Biodevices, Ambala) for the group experimentation and research was used for EMG recording. All procedures were standardized. Three sets of observations were made on each subject. The electrodes were located over the belly of the muscles and oriented along its longitudinal axis. The concentric and eccentric phase of the sit-up exercises were undertaken and were analyzed by paired t-test, that revealed no significant difference (0.05 level). Our findings support the concept that abdominal strengthening exercises can differentially activate various abdominal muscle groups, but contradict some traditionally held assumptions regarding the effects of specific phase exercises.

Introduction

Fitness training exercises are designed to overload specific muscles in order to increase muscular strength and/or endurance. Therefore, one of the greatest challenges physical educators, coaches, trainers, therapist and physicians is to face the selection of appropriate exercises, phases and variations, to best isolate a targeted muscle or muscular groups.

An integrated component of most training programs is the use of exercises to increase abdominal strength, for example, crunches (curl-up), various types of sit-up, and other types of leg rises are all used to increase abdominal strength and endurance, and reduce the risk of lower back injuries.

In recent years numerous companies have capitalized on this trend by developing devices for abdominal exercise. Despite manufacturer claims that these abdominal devices are superior to traditional crunches, published research fails to support these statements (Demont et al. 1999; Eric and Stuart 2000).

Three types of muscle contractions accomplish all motor actions involving skeletal muscle activities: concentric (shortening), eccentric (lengthening), and isometric (constant length). Of the three, isometric and concentric contractions are more widely studied, and the neural mechanisms that mediate isometric and concentric actions are better understood.

Concentric Contraction

During the concentric contraction, the working muscle shortens, pulling the bones on either side of the joint closer together. The amount of force that a muscle is able to generate is increased with the number of motor units utilized.

At the start of this concentric contraction, only a small number of motor units are activated, generating minimal force. On repetition speed at which the movement is completely controlled then (with no swinging) maximum recruitment of fibers is required to generate maximum force, but if you let momentum do some of the work then, you won't use as many muscle fibers to lift the weight. At the end of the concentric contraction, a muscle is in its shortest position. Some exercise physiologists and many bodybuilders recommend that you pause here for a second or two to contract the working muscle as intensely as possible, a technique called peak contraction. Others question the need to stop at any point during the repetition.

Steven Fleck, PhD, CSCS, former head of the physical conditioning program for the U.S. Olympic Committee, believes that using the appropriate resistance is more important than generating a peak contraction. "If the weight is light, you can never reach maximal contraction," he says. "But if you manage the resistance right, you'll get near-maximal contraction at some point during the range of motion."

Eccentric contraction

Whether or not you pause at the end of the concentric half of the repetition, eventually you have to return to the start position. This half of the repetition is called the eccentric phase, which many bodybuilders mistakenly treat as an afterthought. As you lower a dumbbell during a curl, for example, the biceps lengthens, even though it's still contracted to some degree. (Were it not for this contraction, the weight would simply fall back to the start instead of returning in a controlled manner.) During the eccentric phase, nerve impulses continue to signal motor units to fire, even though fewer motor units are incorporated than during the concentric contraction. As a result, more stress is placed upon each of the activated muscle fibers.

Eccentric contractions occur when activated muscles are lengthened. This mode of muscle function occurs frequently in the activities of daily living and in athletic competition.

This review examines the experimental evidence that provides the foundation for our current understanding of the benefits, consequences and control of eccentric contractions. Over the past several decades, numerous studies have established that eccentric contractions can maximize the force exerted and the work performed by muscle; that they are associated with a greater mechanical efficiency; that they can attenuate the mechanical effects of impact forces; and that they reduce the tissue damage associated with exercise.

Eccentric muscle contractions, which generate a significant proportion of our daily-living movements [e.g., walking upstairs (concentric) and downstairs (eccentric); raising a water glass to the mouth (concentric) and returning it to the table (eccentric)], are less well understood.

A major advantage of eccentric muscle actions is that this type of muscle activity develops greater tension than concentric actions (Bigland and Lippold 1954).

Numerous athletic training and recreational conditioning programs also include eccentric muscle activities as a major component of these programs (Alfredson et al. 1998; Bobbert 1990).

Eccentric training induces adaptive changes in the muscle, which may reduce future tissue damage and pain (Hortobágyi et al., 1996).

Eccentric contractions require less energy expenditure, and such energy efficiency may improve the functional capacity of an individual with limited physiological reserves (Bigland-Ritchie and Woods 1986; Moritani et al., 1992).

Review of Literature

Little is known about how eccentric training or exercise affects the CNS. The results of many studies suggest that the CNS may control concentric and eccentric muscle actions differently. One of the most reported observations is that for a given force to be generated, electromyographic (EMG) activities are lower during eccentric than concentric contractions (Bigland and Lippold 1954; Moritani et al. 1992; Tesch et al. 1990).

Despite abundant evidence that different nervous system control strategies may exist for human concentric and eccentric muscle contractions, no data are available to indicate that the brain signal differs for eccentric versus concentric muscle actions.

The kinetic and kinematics information from the muscle and joint movement-related cortical potential

(MRCP) was derived from the electroencephalograph (EEG) signals of the eccentric and concentric muscle contractions. Although the elbow flexor muscle activation (EMG) was lower during eccentric than concentric actions, the amplitude of two major MRCP components was significantly greater for eccentric than for concentric actions. The MRCP onset time for the eccentric task occurred earlier than that for the concentric task. The greater cortical signal for eccentric muscle actions suggests that the brain probably plans and programs eccentric movements differently from concentric muscle tasks (Fang et al 2001).

Hypothesis

Based on the previous research done it is hypothesized that there will be significant EMG differences between the concentric and eccentric phase of contraction in selected abdominal exercises.

Procedure

Subject Ten selected male All India In tervarsity Level Players volunteered to participate in this study. The mean age, height, and body weight of the subjects was 20.6 yrs., 167 cm. and 62 kg, respectively. Subjects were instructed on how to perform each exercise properly prior to collection of data. After receiving an explanation of the experimental protocol, each subject practiced the proper technique. Subject selection was limited to individuals with sufficiently low subcutaneous adipose tissue in order to permit accurate measurement of muscle activity.

Experimental DeviceEMG recordings were recorded from the upper and lower portions of the rectus abdominis. To ensure valid comparisons in our EMG data, range of motion (ROM) and velocity of movement were controlled across devices and subjects.

The skin over the target muscle was abraded and cleaned to assure a low skin resistance. The palpitation techniques were used to determine the muscular quadrants (Kelley, 1971). Bipolar surface electrodes were secured over the bellies of the Upper Umbilicus and Hypogastria. The ground electrode was secured slightly superior to the Lateral Malleolus of the right leg.

Muscle activity was measured using a standard EMG system (Student Physiograph for Group experimentation and research, Biodevices, Ambala). Bipolar silver chloride surface electrodes were placed on the skin overlying the right upper portion of the rectus abdominis (Upper Umbilical), right lower portion of the rectus abdominis (Hypogastria). An unshielded ground electrode was placed on the skin overlying the Lateral Malleolus. The electrodes were oriented parallel to the muscle fibers and an interelectrode distance was maintained consistent from subject to subject. Prior to electrode application, the skin over each muscle was shaved and cleansed with sprit to reduce the impedance at the skin electrode interface. EMG recordings were determined and the analysis was conducted as elaborated by Kelley, 1971.

Experimental Design

After appropriate instruction on the proper technique for execution of the abdominal exercise, subjects performed three abdominal exercises. The mechanics of performing abdominal exercises in this study used the traditional sit-up exercises. The traditional sit-up exercises: Straight leg sit-up, bent leg sit-up, and crunches with the hands clasped in front (on the chest). All subjects were tested from the supine lying position. Each subject was instructed to perform the exercises as per the instructions and practice training given. All data for each subject were collected during a single session. To ensure temporal consistency, each subject was instructed to perform each set with a given rhythm along the amplified watch beat through a constant ROM and at a constant speed during the concentric and eccentric phase. An angle-marked projector (24°, 48° and 72°) was used to ascertain the speed of motion and was used to pace each phase of exercise at a rate of 3.00 seconds (concentric and eccentric). Sufficient rest was allowed between sets to avoid fatigue. None of the subjects commented that they felt fatigued at any point during their data collection session.

Statistical Analyses

Statistical analyses performed on the mean EMG amplitude values using a paired t-test procedure for each of the 3 exercises. Reported differences were accepted as statistically non significant at $p \geq 0.05$

CONCENTRIC AND ECCENTRIC PHASE

Tabulated t-value: tab.t = 2.26

	Cal.-t	Bent Leg Sit-ups	Cal.-t	Crunches	Cal.-t
Upper Umbilicus	1.41	Upper Umbilicus	1.43	Upper Umbilicus	0.77
Hypogastria	0.63	Hypogastria	0.46	Hypogastria	0.29

Significant = Cal.t > tab.t
Non Significant = Cal.t < tab.t

Result

The statistical analysis paired t-test showed no significant differences between the concentric and eccentric phase of contraction during the three selected abdominal exercises.

Mean EMG data showed variations that for each exercise tested in the upper umbilicas (Up.Um.) and hypogastria (Hypo) region of the rectus abdominis.

The mean values of the EMG Amplitudes of during Concentric and Eccentric phase of Abdominal Exercises in Rectus Abdominis muscles.

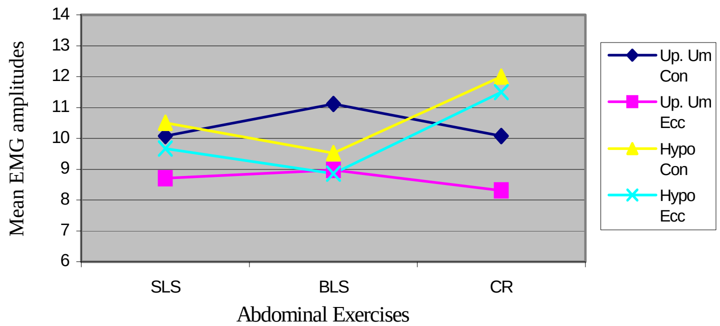
Table-1

Sit – up exercises ⇓	Upper Umbilicus		Hypogastria	
	Con.	**Ecc.**	**Con.**	**Ecc.**
SLS	**10.00**	**8.70**	**10.51**	**9.67**
BLS	**11.10**	**8.97**	**9.52**	**8.86**
CR	**10.00**	**8.31**	**12.00**	**11.49**

SLS- Straight Leg Sit-up; BLS- Bent Leg Sit-up; CR-Crunches

Graphical representation of concentric and eccentric phases of contraction during abdominal exercises in rectus abdominis muscle

Figure-1



Upper Umbilicus of the Rectus Abdominis

The Upper Umbilicus during straight leg sit-up exercise showed a mean differences of 1.375 (con.-10.079 & ecc.-8.704), bent leg sit-up of 2.140 (con.-11.112 & ecc.-8.972) and the crunches is of 1.767 (con.- 10.079 & ecc.-8.312).

All mean values were not significantly different from each other.

Hypogastria of the Rectus Abdominis

The Hypogastria region during straight leg sit-up exercise showed a mean differences of 0.840 (con.-10.506 & ecc.-9.666), bent leg sit-up of 0.660 (con.-9.519 & ecc.-8.859) and the crunches is of 0.508 (con.- 12.000 & ecc.-11.492).

All mean values were not significantly different from each other.

Discussion

This study supports previous findings that there is no significant difference in abdominal muscle intensity between the concentric and eccentric contraction and on any traditional abdominal exercises without adding any external resistance during the course of exercises. But there is increase in abdominal muscle activity during the course of exercises.

The principal reason for the lower (non-significant) abdominal activity in the eccentric phase compared to the concentric phase, was that the vertical lift against the gravitational force provide enough resistance to require substantial muscle recruitment in the concentric contraction. The findings are similar to those reported by Clark et al (2003).

The minimal abdominal muscle recruitment while performing downward motion (eccentric) in a supine lying position produced enough load to require comparable abdominal muscle activity due to the controlled motion as recorded during the abdominal exercise.

In order to provide greater overload to the abdominal musculature on a traditional abdominal exercise, additional resistance must be provided. In summary, all abdominal exercise elicited abdominal muscle activity during concentric and eccentric phase of contraction when used with proper technique. The perfect way to perform an abdominal exercise is to elicit significantly greater abdominal muscle recruitment.

Practical Applications

The data collected in this study verify that abdominal exercises used in a supine position elicit abdominal muscle activity when performing a traditional abdominal exercise.

As the different traditional techniques of abdominal exercises do not differ significantly in the activation of the designated muscles, hence any one of these exercise techniques may be performed to enhance strength and/or endurance.

As there is no significant difference between the concentric and eccentric phase of contraction during the selected abdominal exercises, so the ECCENTRIC PHASE of contraction should be performed consistently, because the eccentric phase of contraction can maximize the force exerted and the work performed by muscle; associated with a greater mechanical efficiency; can attenuate the mechanical effects of impact forces and reduce the tissue damage, pain and injuries associated with exercise.

References

Alfredson, H.; Pietilae, T; Jonsson, P.; Lorentzon, R., Heavy-load eccentric calf muscle training for the treatment of chronic Achilles tendinosis. *American Journal of Sports Medicine,* Baltimore (Md.), 26,3, pp. 360-366, 1998.

Bigland, B, and Lippold OCJ The relation between force, velocity and integrated electrical activity in human muscles. *J Physiol* (Lond) 123: 214-224, 1954.

Bigland-Ritchie, B, Furbush F, and Woods JJ. Fatigue of intermittent submaximal voluntary contractions: central and peripheral factors. *J Appl Physiol* 61: 421-429, 1986.

Bobbert, M, and Harlaar J. Evaluation of moment-angle curves in isokinetic knee extension. *Med Science Sports Exerc* 25: 251-259, 1992.

Clark KM, Holt LE, Sinyard J. Electromyographic comparison of the upper and lower rectus abdominis during abdominal exercises. *Journal of Strength and Conditioning Research,* 17(3): 475 – 483, 2003.Demont RG, Lephart SM, Giraldo JL, Giannantonio FP, Yuktanandana P, Fu FH.

Comparison of two abdominal training devices with an abdominal crunch using strength and EMG measurements, *J Sports Med Phys Fitness.* 39(3):253-8, Sep.1999.

Eric Sternlicht and Stuart Rugg Electromyographic Analysis of Abdominal Muscle Activity Using Portable Abdominal Exercise Devices and a Traditional Crunch, *The Journal of Strength and Conditioning Research*: Vol. 17, No. 3, pp. 463–468, 2000.

Fang,Y. Siemionow,V. Sahgal,V., Xiong,F, and Yue,G. H. Greater Movement-Related Cortical Potential During Human Eccentric Versus Concentric Muscle Contractions, *The Journal of Neurophysiology* Vol.-86 No.4, pp.1764-1772, October 2001.

Hortobagyi, T, Barrier J, Beard D, Braspennincx J, Koens P, Devita P, Dempsey L, and Lambert J. Greater initial adaptations to submaximal muscle lengthening than maximal shortening. *J Appl Physiol* 81: 1677-1682, 1996.

Moritani, T. Time course of adaptations during strength and power training. In: Strength and Power in Sports, *edited by Komi PV.. Oxford, UK: Blackwell Scientific*, p. 266-278. 1992.

Tesch, PA, Dudley GA, Duvoisin MR, Hather BM, and Harris RT. Force and EMG signal patterns during repeated bouts of concentric and eccentric muscle actions. *Acta Physiol Scand* 138: 263-271, 1990.

Wilkins, H. A., Petersen, S. R., K. M. Bagnall, J. Wessel, H. A. Quinney, and H. A. Wenger. The influence of isokinetic concentric resistance training on concentric and eccentric torque outputs and cross-sectional area of the quadriceps femoris. *Can. J. Sport Sci*. 13: 76P-77P, 1988.