South African Journal for Research in Sport, Physical Education and Recreation, 2007, 29(2): 59-66.
Suid-Afrikaanse Tydskrif vir Navorsing in Sport, Liggaamlike Opvoedkunde en Ontspanning, 2007, 29(2): 59-66.
ISSN: 0379-9069

ELECTROMYOGRAPHIC COMPARISON OF CONCENTRIC AND ECCENTRIC CONTRACTION PHASE IN ABDOMINAL EXERCISES

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ABSTRACT

The study was conducted to compare the Electromyographic (EMG) activity variation of contractions (concentric and eccentric) during three different abdominal exercises (sit-up) exercises on rectus abdominal (upper and lower rectus). The sit-up exercises were: straight leg sit-up, bent leg sit-up and crunches. The EMG activity during exercise was recorded on ten selected male All India Intervarsity players. Their mean age, height and weight were 20.6 yrs (SD 1.90), 167.4 cm (SD 4.92) and 62.6 kg (SD 2.45) respectively. The Student Physiograph (Biodevices) for the group experimentation and research was used for EMG activity recording with the sensitivity set at 100µv /cm, amplitude signals bandwidth of 50Hz and the paper speed at 25mm/sec. Bipolar silver chloride surface electrodes of diameter of 1.3 cm were located over the belly on upper rectus and right lower rectus of the rectus abdominis muscle and oriented along its longitudinal axis, and an interelectrode distance was maintained consistent from subject to subject.. An unshielded ground electrode was placed over the lateral malleolus. The skin over each muscle was shaved and cleansed with sprit to reduce the impedance at the skin electrode interface. Electromyographic activity (EMG) was determined by averaging frequency, duration, and amplitude. Subjects performed one repetition for each sit-up exercises from the supine lying position and data were collected during a single session. To ensure consistency in the speed and velocity of the movement, subject performed each sit-up exercise with a given rhythm along the amplified watch beat, through a constant range of movement round an angle-marked projector at a rate of 3.00 seconds each contraction phase. Paired t-test analysis was used to compare mean electromyographic activity of concentric and eccentric contraction phase of upper rectus and lower rectus during sit-up exercises. Results showed no significant differences ($p \leq 0.05$) in muscle activation among the conditions.

Key words: Electromyographic; Sit-up; Abdominal; Sports.

INTRODUCTION

Exercises are designed to overload specific muscles in order to enhance motor performance. The greatest challenge for physical educators, coaches, trainers, therapists and physicians is in the selection of appropriate exercises and variations, to best isolate a targeted muscle or muscle groups.

The mid-section of the abdominal muscles consists of the rectus abdominis. The rectus abdominis is a long, flat band of muscle fibers extending vertically between the pubis and the cartilages of the fifth, sixth, and seventh ribs on the front part of your trunk. Its right and left halves are separated in the middle by a strong tendinous sheath known as the linea alba. There are three horizontal tendinous creases that separate into four section i.e. epigastria and upper umbilical (upper rectus) and lower umbilical and hypogastria (lower rectus).

Electromyographic (EMG) assessment of anterior trunk muscles, most frequently the rectus abdominis has been widely reported across a range of activities, including lifting (Machado de Sousa & Furlani, 1974) and various types of sit-up exercises in adults (Noble, 1981; Guimaraes *et al.*, 1991; Bankoff & Furlani, 1984) and children (Moraes *et al.*, 1995).

Sit-up exercises are used extensively to improve abdominal muscle strength. The goals of programs designed to strengthen the abdominal muscles include performance enhancement, postural improvement, and lowering the risk of low back pain.

The different muscle contractions accomplishing the motor actions involving skeletal muscle activities are concentric (shortening), eccentric (lengthening) and isometric (constant length). Of the three, isometric and concentric contractions are more widely studied, and the mechanisms that mediate isometric and concentric actions are better understood. A muscle is in its shortest position at the end of the concentric contraction. Pulling the bones closer together on either side of the joint by shortening the working muscles is the concentric contraction phase. Eventually the muscle has to return to the start position, whether or not a pause at the end of the concentric or half contraction only. The returning back of the repetition is called the eccentric contraction phase. Eccentric contractions occur when activated muscles are lengthened. This mode of muscle function occurs frequently in the activities of daily living and in athletic movements.

In the process of contraction the number of motor units activated determines the amount of force that the working muscle is able to generate. At the beginning of concentric contraction a small number of motor units are activated generating minimal force for the movement. In the course of completely controlled movement maximum motor units are activated (recruitment) to generate maximum force. But if the movement is assisted by momentum then as many motor units assigned will not be used. If and when more forces are required, then additional motor units are called upon.

During the eccentric contraction phase, nerve impulses continue to signal motor units, even though fewer motor units are incorporated than during the concentric contraction phase (Sarti *et al.*, 1996). As a result, more stress is placed upon each of the activated muscle fibers.

Studies (Miller & Medeiros, 1987; Anderson *et al.*, 1997) have reported that eccentric contractions generates maximum force exertion and enhances muscular work performance; that are associated with a greater mechanical efficiency; that can attenuate the mechanical effects of impact forces; and also reduce the tissue damage associated with exercise. A major advantage of eccentric muscle actions is that this type of muscle activity develops greater tension than concentric actions. Numerous athletic training and recreational conditioning programs also include eccentric muscle activities as a major component of these programs (Bobbert & Harlaar, 1990; Alfredson *et al.*, 1998). 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 *et al.*, 1986; Moritani, 1992).

Very little is known about how eccentric training affects the Central Nervous System. The results of the studies (Yang & Winter, 1984; Komi, 1986) suggested that the CNS controlled concentric and eccentric muscle acts differently. One of the most reported observations is that for a given force to be generated. Electromyography (EMG) activity shows lower recruitment of motor units during eccentric than concentric contractions (Bigland & Lippold, 1954; Moritani, 1992).

There are abundant evidence that different nervous system controls exist for concentric and eccentric muscle contractions, but have no data available to indicate that the nervous system signal differ for eccentric and concentric muscle actions.

Significant proportions of our daily-living movements are of eccentric contraction force generation e.g., downstairs (eccentric); lowering of weight towards the ground, placing of books on the shelf (eccentric), etc, but are less well understood.

From the preceding practical and the theoretical understanding it is hypothesized, that there will be significant differences between the concentric and eccentric contraction phase in upper and lower rectus during abdominal exercises.

PROCEDURE

Subjects

Informed consent from 10 male All India Intervarsity Level Players of hockey, soccer and track & field were taken for this study. The mean data of anthropometrics description of age, height, and body weight were 20.6 yrs (SD 1.90), 167 cm (SD 4.92) and 62 kg (SD 2.45), respectively (Table 1).

The subject selection was limited to individuals with prominent abdominals indicating sufficiently low subcutaneous adipose tissue. Prior to the data collection, subjects were explained about the proper technique of execution of sit-up exercises. After explanation of the experimental protocol, each subject practiced the proper technique with the correct sequence of beat on which they were to perform the sit-up exercise.

Apparatus

A standard electromyography (EMG) system (Student Physiograph for Group experimentation and research, Biodevices, Ambala) was used to measure the muscle activity. The sensitivity for EMG recording was set at $100\mu v$ /cm, with amplitude signals bandwidth of 50Hz and the speed of the paper set at 25mm/sec. Bipolar silver chloride surface electrodes of diameter of 1.3 cm were placed on the skin overlying the right upper portion (upper rectus) of the rectus abdominis and right lower portion (lower rectus) of the rectus abdominis. 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. Electromyographic activity (EMG) was determined by averaging frequency, duration and amplitude, the process elaborated by Kelley (1971).

Methodology

The abdominal exercises in this study used were the traditional sit-up exercises. The traditional sit-up exercises were: 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 for one complete repetition. Subjects performed all three sit-up exercises and data for each subject were collected during a single session.

To ensure consistency in the velocity of the movement, each subject was instructed and practiced to perform each sit-up exercise with a given rhythm along the amplified watch beat, through a constant range of movement and a constant speed during the concentric and eccentric phase. An angle-marked projector (24°, 48° and 72°) was used to ascertain the range of movement and speed of motion. The subjects had to complete each phase of exercise at a rate of 3.00 seconds. In the concentric contraction phase, each subject performed sit-up exercise from supine lying position to 24° in the first second, then to 48° in the second, second and to 72° in the third second. And in the eccentric contraction phase, the subject moved downward from 72° to 48° in the first second, then to 24° in the second, second and to supine lying position in the third second. Sufficient rest was allowed between each repetition to avoid fatigue.

A paired t-test analysis was performed to compare the mean EMG activity of the concentric and eccentric contraction phase during sit-up exercises. The statistical significance of the three sit-up exercises and two muscle sites were examined ($p \leq 0.05$).

RESULTS

The mean of EMG activity in straight leg sit-up for concentric and eccentric contraction phase of upper rectus was $10.00\mu v$ and $8.70\mu v$ respectively with a mean difference (MD) of 1.30 and standard deviation (SD) 2.14; and lower rectus was $8.31\mu v$ and $9.67\mu v$ respectively with a MD of 1.36 and SD of 4.83. The mean of EMG activity in bent leg sit-up of concentric and eccentric contraction phase of upper rectus was $11.10\mu v$ and $8.97\mu v$ respectively with a MD of 2.13 and SD of 3.47; and lower rectus was $9.52\mu v$ and $8.86\mu v$ respectively with a MD of 0.66 and SD of 3.17. The mean of EMG activity in crunches of concentric and eccentric contraction phase of upper rectus was $10.00\mu v$ and $8.31\mu v$ respectively with a MD of 1.69 and SD of 4.94; and lower rectus was $12.00\mu v$ and $11.49\mu v$ respectively with a MD of 0.51 and SD of 3.88 (Table 2). Comparing the mean difference in EMG activity of concentric and eccentric contraction phase of upper and lower rectus during the straight leg sit-up, bent leg sit-up and crunches revealed no statistical significant difference between them. For straight leg sit-up in upper and lower rectus, the calculated-t was 1.41 and 0.63 respectively, for bent leg sit-up in upper and lower rectus the calculated-t was 1.43 and 0.46 respectively and for crunches in upper and lower rectus the calculated-t was 0.77 and 0.29 respectively (table-3).

DISCUSSION

The hypothesis was rejected, as the results of this study apparently indicate no significant difference in muscle activity for the concentric and eccentric contraction phase of abdominal muscle (UR and LR) during abdominal exercises. This study supports the previous studies of Andrew *et al.* (1993) and Hildenbrand and Noble (2004). But revealed a higher mean EMG activity difference in concentric than the eccentric contraction phase. The reason for the differences between concentric and eccentric contraction phase may be due to the vertical lift against the gravitational force that provided enough resistance to require substantial motor unit recruitment in concentric contraction phase whereas assisted gravitational force in eccentric phase required subsequently lower motor unit recruitment, which produced enough resistance to require comparable muscle activity due to the controlled motion as recorded during the abdominal exercise.

The result in this study further verifies that the muscle activity in concentric and eccentric contraction phase of upper and lower rectus muscle during abdominal exercises show no significant difference and thus reveal that both phases have equal importance. To impress upon here that the eccentric phase of contraction should also be performed religiously as it is associated with a greater mechanical efficiency and maximizes the force exertion; the work performance; attenuate the mechanical effects of impact forces and reduce the tissue damage, pain and injuries associated with exercise (Bigland-Ritchie *et al.*, 1986; Miller & Medeiros, 1987; Moritani, 1992; Hortobágyi *et al.*, 1996; Anderson *et al.*, 1997).

In summary, all abdominal exercises elicited similar 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 by taking the eccentric contraction phase into account.

TABLE 1: **DESCRIPTIVE ANTHROPOMETRICS DATA**

	No.	Sex	Age (Yrs)	Height (cm)	Weight (kg)
Subjects	10	Male	18-24	160.40-174.00	56-64
Mean			20.6	167.00	62.00
SD			1.90	4.92	2.45

TABLE 2: **THE MEAN VALUES OF THE EMG ACTIVITY DURING CONCENTRIC AND ECCENTRIC PHASE OF ABDOMINAL EXERCISES IN RECTUS ABDOMINIS MUSCLES**

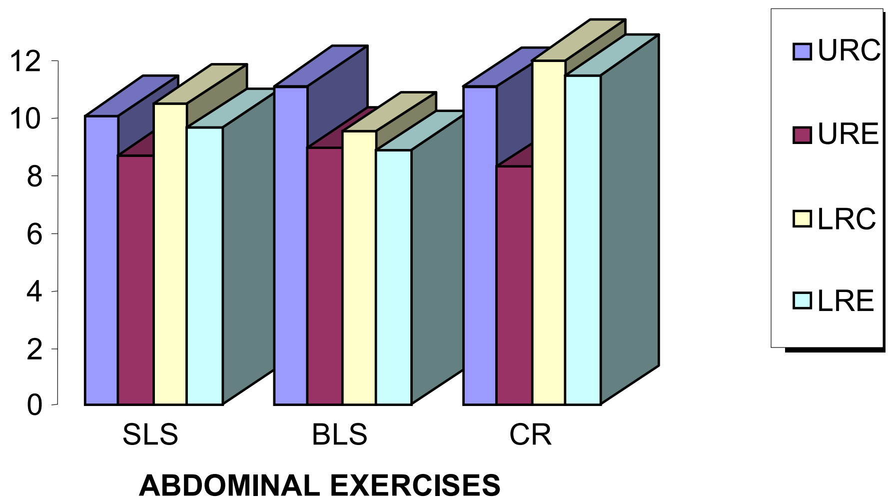
Sit-up Exercises	Upper Rectus				Lower Rectus			
	Con	Ecc	MD	SD	Con	Ecc	MD	SD
SLS	10.00	8.70	1.30	2.14	8.31	9.67	1.36	4.83
BLS	11.10	8.97	2.13	3.47	9.52	8.86	0.66	3.17
CR	10.00	8.31	1.69	4.94	12.00	11.49	0.51	3.88

SLS- Straight Leg Sit-up; BLS- Bent Leg Sit-up; CR-Crunches, Con- Concentric;
Ecc- Eccentric; MD- Mean difference; SD-Standard deviation.

TABLE 3: **THE RESULT OF PAIRED T-TEST ANALYSIS ON CONCENTRIC AND ECCENTRIC PHASE OF ABDOMINAL EXERCISES IN RECTUS ABDOMINIS MUSCLES**

Straight Leg Sit-ups	SD	Cal.-t	Bent Leg Sit-ups	SD	Cal.-t	Crunches	SD	Cal.-t
Upper Rectus	2.14	1.41	Upper Rectus	3.47	1.43	Upper Rectus	4.94	0.77
Lower Rectus	4.83	0.63	Lower Rectus	3.17	0.46	Lower Rectus	3.88	0.29

Tabulated t-value: tab.t = 2.26 , Significant = Cal.t > tab.t ; Insignificant = Cal.t < tab.t



SLS- Straight Leg Sit-up; BLS- Bent Leg Sit-up; CR- Crunches; URC- Upper Rectus Concentric; URE- Upper Rectus Eccentric; LRC- Lower Rectus Concentric; LRE- Lower Rectus Eccentric.

FIGURE 1: **GRAPHICAL REPRESENTATION OF CONCENTRIC AND ECCENTRIC PHASES OF CONTRACTION DURING ABDOMINAL EXERCISES IN RECTUS ABDOMINIS MUSCLE**

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(Subject editor: Prof. P.E. Krüger)