An Electromyography Study on Constant Location Versus Changing Location Swiss Ball Exercises in the Recruitment of Abdominal Muscle in Chronic Low Back Pain Patients

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Abstract

Background: Swiss balls provide an unstable surface which may result in an increased need for force output from trunk muscles to provide adequate spinal stability or balance.

Purpose of the Study: The purpose of the study was to compare electromyographic (EMG) activity of the abdominal muscles between constant location exercise and changing location exercise.

Study Design: Prospective Experimental Design.

Methods: The myoelectric activity of four abdominal muscles (Upper and Lower Rectus Abdominus, External Oblique, and Internal Oblique) was quantified during the performance of constant location and changing location Swiss ball exercises. Group-A, (n=10) have performed constant location exercise (SCALE constant location exercise) and Group-B, (n=10) have performed changing location exercise (INDIAN FAKIR changing location exercise) with Swiss ball. Paired and Unpaired 't' test was used to determine the abdominal muscle activity of each muscle in constant location and changing location exercise.

Results: There was statistically significant ($p < 0.05$) difference in muscle activity (Upper and Lower Rectus Abdominus, External Oblique, and Internal Oblique) between constant location and changing location exercises.

Discussion: However, there was large degree of variability across subjects suggesting that individuals respond differently to both the types of exercises. These findings suggest that changing location exercises offers more work to the abdominal muscles in compare to constant location exercise.

Conclusion: Changing location Swiss Ball exercises offers more work to the abdominal muscles (Upper and Lower Rectus Abdominus, External Oblique, and Internal Oblique) in compare to constant location exercise.

Keywords: *EMG; Swiss Ball; Rectus Abdominus; External Oblique; Internal Oblique*

Introduction

Chronic low back pain is a major health care problem in industrialized societies, and inadequate strength of trunk muscles appears to be related to the development of chronic low back pain. Several authors have described the important role of strong abdominal muscles in both postural control and prevention of low back injury. Patients with chronic low back pain demonstrate decreased levels of strength for trunk flexion when compared to normal subjects [1].

Adequate spinal stability is important in the prevention and treatment of low back injuries [2]. Stability is achieved through the co activation of trunk muscles; therefore, strength training has been postulated to be beneficial in training trunk muscles to provide stability. Swiss balls have been incorporated into strength training regimes and touted as a means to more effectively train the abdominal muscles.

Swiss balls are currently used to replace stable surface during the performance of strength training exercises. Vera-Garcia., *et al.* [3] documented increases in rectus abdominis and external oblique activity using curl ups when performed on a Swiss ball compared with a stable surface. Mori [4] documented trunk muscle activation levels during a variety of trunk muscle exercises showing that substantial levels of trunk muscle activity occurs. However, because the exercise tasks were not also performed on a stable surface it is unknown how much the Swiss ball's instability contributed to a demand for muscle activation.

Studies have documented the myoelectric activity of the trunk muscles during exercises specifically designed to asses and train the trunk muscles. A growing literature suggests that there are significant differences in SEMG activity between persons with and without LBP, and that SEMG measures can accurately differentiate these persons. These findings suggest that SEMG may serve as an objective marker of LBP.

Surface Electromyography (SEMG) is a technique to measure muscle activity non invasively using surface electrodes placed on the skin overlying the muscle. Unlike Needle Electromyography (NEMG), SEMG electrodes record from a wide area of muscle territory, have a relatively narrow frequency band (range, 20 to 500 Hz), have low-signal resolution, and are highly susceptible to movement artifact. SEMG electrodes typically are approximately 10 mm in diameter and usually are passive (i.e., they are simple conductive surfaces requiring low skin resistance). They can, however, be active, incorporating preamplifier electronics that lessen the need for low skin resistance and improve the signal-to-noise ratio. SEMG can record both voluntary and involuntary muscle activity in addition to externally stimulated muscle action potentials such as motor evoked potentials after central or peripheral nerve stimulation [5].

Safe exercises on Swiss ball have been advocated and thoroughly investigated with a detailed biomechanical model [6] which provide an excellent balance between muscle stress and low compressive/ shear penalty, the same cannot be argued for the constant and changing location exercises incorporating with the use of Swiss balls. The study has been carried out because of the popularity of Swiss balls and the lack of research investigating their influence on electromyographic activity on abdominal muscle activity during constant and changing location exercises.

Methods

Participant Characteristics

In Group-A (n = 10: Six males and Four females) with average age of (standard deviation) 46 (9.2), average height in cm (standard deviation) 165.8 (5.24) and average mass in kg 70 (3.78) and in Group-B (n = 10: Four males and Six females) with average age of (standard deviation) 47 (5.05), average height in cm (standard deviation) 166.3 (4.83) and average mass in kg 68 (4.23) were recruited by convenience sampling method consisting of chronic low back pain patients. Participants read and signed an information and consent form to participate in the study.

Selection Criteria

Subjects with LBP were excluded (by clinical exam or interview) if they reported pain less than three months, vertebral fracture, tumor or infection, spinal stenosis, previous spinal surgery, systemic infection, balance or cardiovascular disorders, current pregnancy, history of any surgery in the three months prior to testing, uncorrected vision problems, scoliosis or kyphosis, injury to the lower extremity, or radiating pain below the knee that would be consistent with a disc herniation.

Electrode Placement

Skin preparation included cleaning and abrading the skin with alcohol solution prior to applying the electrodes to reduce skin impedance. Four sites on participants' right sides were chosen for electrode placement: (McGill and Collegues)

(1) Upper rectus abdominis (URA), 2 cm lateral and 3 cm superior to the umbilicus;

(2) Lower rectus abdominis (LRA), 2 cm lateral and 3 cm inferior to the umbilicus;

(3) External oblique abdominis (EOA), 15 cm lateral to the umbilicus; and

(4) Internal oblique abdominis (IOA), below the EOA electrode, just superior to the inguinal ligament.

A reference electrode was placed over the eleventh rib.

Instrumentation

EMG data was collected using disposable bipolar Ag-Ag Cl disc surface electrodes with a diameter of one cm, adhered bilaterally over the muscle groups with a centre-to-centre spacing of 2 cm. Raw EMG was amplified between 1000 and 10,000 times, depending on the subject. The amplifier had a CMRR of 10,000:1. Raw EMG was band pass filtered 10 and 1000 HZ.

Normalization task procedure: (Maximum Voluntary Isometric Contraction)

Subjects were required to perform maximum voluntary contractions for the abdominal musculature. The following positions were employed for MVIC test¬ing [7,8] for the upper and lower rectus abdominis the subject was in supine, with hips and knees flexed 90°, feet supported, and trunk maximally flexed with resistance provided at the shoulders by a tester pushing in the trunk extension direction; for the external oblique the subject was in supine, with hips and knees flexed 90°, feet supported, and trunk maximally flexed and rotated to the left, with resistance at the shoul¬ders by a tester pushing in the trunk ex¬tension and right rotation directions; for the internal oblique the subject was in supine, with hips and knees flexed 90°, feet supported, and trunk maximally flexed and rotated to the right, with resistance at the shoulders by a tester pushing in the trunk extension and left rotation directions.

Exercises Descriptions

After being instrumented, subjects performed the normalization tasks and then the 2 exercises on Swiss ball. The two Swiss ball abdominal exercises are shown in Figure 1 and 2. No subject had prior experience in per¬forming the Swiss ball exercises. During the pretest session, each sub¬ject received instructions from a physical therapist that explained and demonstrat¬ed proper execution of each exercise. An appropriately sized Swiss ball was used and adjusted in accordance with each subject's height: subjects with a height between 150 and 165 cm used a 55-cm ball, those with a height between 165 and 180 cm used a 65-cm ball, and those with a height greater than 180 cm used a 75-cm ball. The Swiss ball was also inflated according to the subject's weight, so that when a subject was sitting erect and cen¬tered on the ball, with feet together and flat on the ground, the subject's hips and knees were flexed approximately 90° and the thighs were parallel with the floor.

Scale Constant Location Exercises

Starting position: Sit upright on the ball with both feet on the floor. The hips, knees and feet at 90 degrees, with the arms in an oval raised above the head in the midfrontal plane (Figure 1).

Procedure: The Swiss ball is pulled toward the feet, the heels lift up to allow for more movement. The aligned trunk head and arms lean backward; the abdominal muscles are activated. Then the Swiss ball is pushed backward; the heels keep in contact with the floor; the fore foot lifts up. Where the aligned trunk and head lean forward; the arms are lowered to the level of the shoulders. The abdominal muscles are activated until the upright position is achieved. When leaning forward, the back extensor muscles are activated holding the dynamically stable trunk against gravity.

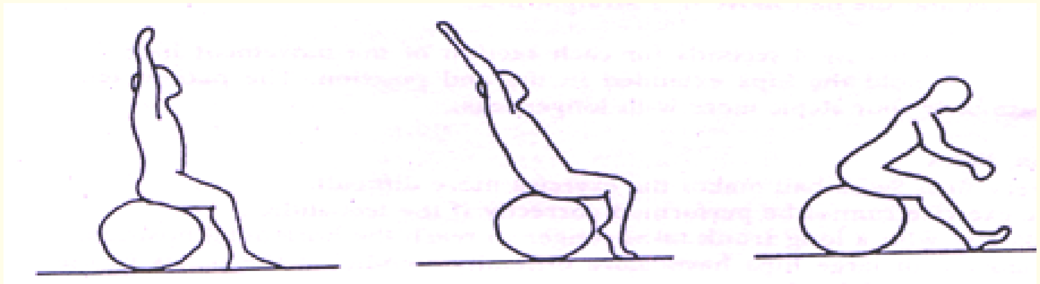

Figure1: *Scale Constant Location Exercises.*

Indian Fakir Changing Location Exercises:

Starting position: Sit centrically on the Swiss ball. The arms are at 90 degrees forward flexion forming an oval in a transverse plane (Figure 2).

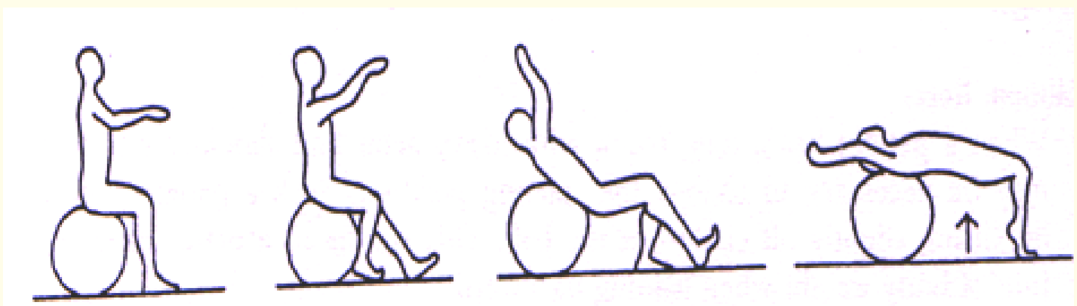

Figure 2: *Indian Fakir Changing Location Exercises.*

Procedure: The arms move upward and backward as the trunk leans backward. When the ball begins to roll forward steps allow for more rolling of the ball. When the Swiss ball rolls more cranially, the strain on the abdominal muscles decreases and the activity of the hip and back extensor muscles increases under the bridge. The arms which are extended above the head initiate the movement by swinging in a ventral/caudal direction taking the trunk along. Reactive steps and movement of the trunk from the horizontal back to the vertical position. As the Swiss ball moves caudally the activity of the back extensor and hip extensor muscle decrease as the load on the abdominal muscle increases.

EMG data were collected during 5 repetitions for each exercise. Each repetition was performed in a slow and controlled manner, using the 3-second cadence and 1-second rest between repetitions as previously described.

Data Processing

Raw EMG signals were full-waved rectified, smoothed with a 10-millisecond moving-average window, and linear en¬veloped, then averaged over the entire duration of each exercise repetition or MVIC performed [7,8]. The beginning and end of each repetition for each exercise were manually determined by assessing when muscle activity was at baseline during the rest periods, when muscle activity began to rise during the begin¬ning of a repetition and at the end of the rest interval, and when muscle ac¬tivity returned back to baseline at the end of the repetition and at the begin¬ning of the rest interval. For each repeti¬tion, the EMG data were normalized for each muscle and expressed as a percent¬age of a subject's highest corresponding MVIC trial, which was determined by calculating throughout the 5-second MVIC the highest average EMG signal over a 1-second interval. Normalized EMG data were then averaged over the 5-repetition trials performed for each exercise and used in statistical analyses.

Statistical Analysis: Paired t test and Independent t test was used to determine if a difference in type of swiss ball exercise influenced abdominal muscle activity in chronic back pain patients.

Results

Using Unpaired 't' test

Comparing Pre test EMG recruitment score of Upper Rectus Abdominus, Lower Rectus Abdominus, Internal Oblique and External Oblique of Group-A and Group-B:

Pre test mean EMG recruitment score of Upper Rectus Abdominus, Lower Rectus Abdominus, Internal Oblique and External Oblique of Group-A is 810, 440, 282, 255 and for Group-B is 809, 426, 292, 272. After analyzing the data calculated 't' value is 0.036, 1.835, 2.436, and 2.916 respectively, the table value is 2.093. The results shows that calculated 't' value is less than table value ($p < 0.05$) for Upper rectus abdominus muscle and Lower rectus abdominus and calculated 't' value is more than table value ($p < 0.05$) for Internal oblique and External Oblique. Results showing that there is no significant difference between Group-A and Group-B in Upper and Lower Rectus Abdominus muscle recruitment and significant difference between Group-A and Group-B in Internal Oblique and External Oblique muscle recruitment.

Comparing Post test EMG recruitment score of Upper Rectus Abdominus, Lower Rectus Abdominus, Internal Oblique and External Oblique of Group-A and Group-B:

Post test mean EMG recruitment score of Upper Rectus Abdominus, Lower Rectus Abdominus, Internal Oblique and External Oblique of Group-A is 504,265,143,143 and for Group-B is 602, 315, 218, 197. After analyzing the data calculated 't' value is 8.283, 6.516, 13.697, 9.028 respectively, the table value is 2.093. The results shows that calculated 't' value is more than table value ($p < 0.05$) for Upper rectus abdominus, Lower rectus abdominus, Internal oblique and External Oblique. Results showing that there is significant difference between Group-A and Group-B in Upper and Lower Rectus Abdominus, Internal Oblique and External Oblique muscle recruitment.

Using Paired 't' test

Comparing Pre and Post test EMG recruitment score of Upper Rectus Abdominus, Lower Rectus Abdominus, Internal Oblique and External Oblique of Group-A:

The mean pre test EMG recruitment score of Upper Rectus Abdominus, Lower Rectus Abdominus, Internal Oblique and External Oblique is 810, 440, 282, 255 and the mean post test EMG recruitment score of Upper Rectus Abdominus, Lower Rectus Abdominus, Internal Oblique and External Oblique is 504, 265, 143, 143. After analyzing the data the calculated 't' value is 27.41, 17.07, 26.80, 16.54 and the table value is 2.262. The results shows that calculated 't' value is greater than table value ($p < 0.05$) showing that there is significant difference between the scores in pre and post test scores.

Comparing Pre and Post test EMG recruitment score of Upper Rectus Abdominus, Lower Rectus Abdominus, Internal Oblique and External Oblique of Group-B:

The mean pre test EMG recruitment score of Upper Rectus Abdominus, Lower Rectus Abdominus, Internal Oblique and External Oblique is 809, 426, 292, 272 and the mean post test EMG recruitment score of Upper Rectus Abdominus, Lower Rectus Abdominus, Internal Oblique and External Oblique is 602, 315, 218, 197. After analyzing the data the calculated 't' value is 15.20, 15.37, 14.51, 12.67 and the table value is 2.262. The results shows that calculated 't' value is greater than table value ($p < 0.05$) showing that there is significant difference between the scores in pre and post test scores.

Statistical analysis shows (Figure 3) in Group-A, 62% muscle recruitment in Upper Rectus Abdominus, 60% in Lower Rectus Abdominus, 51% in Internal Oblique and 56% in External Oblique. In Group-B, 74% muscle recruitment in Upper Rectus Abdominus, 73% in Lower Rectus Abdominus, 74% in Internal Oblique and 72% in External Oblique from the initial value. When comparing the percentage of muscle recruitment in Group-A and Group-B, Shows there is much more muscle recruitment in Group-B (changing location exercise) than Group-A (constant location exercise) at the end of treatment program.

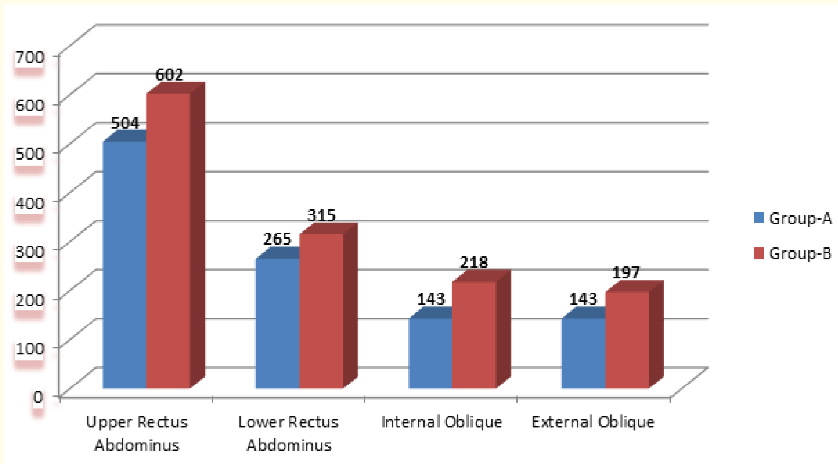

Figure 3: *Comparative Abdominal muscle recruitment values in Group-A and Group- B.*

Group	Pre Test Score	Unpaired t – test (2.093)	Post Test Score	Independent t – test (2.093)	Paired t - test (2.262)	% of recruitment
A	810	0.036	504	8.283	27.41	62%
B	809		602		15.20	74%

Table 1: *Upper Rectus Abdominus muscle activity in Group-A and Group-B.*

Group	Pre Test Score	Unpaired t – test (2.093)	Post Test Score	Independent t – test (2.093)	Paired t - test (2.262)	% of recruitment
A	440	1.835	265	6.516	17.07	60%
B	426		315		15.37	73%

Table 2: *Lower Rectus Abdominus muscle activity in Group-A and Group-B.*

Group	Pre Test Score	Unpaired t – test (2.093)	Post Test Score	Independent t – test (2.093)	Paired t - test (2.262)	% of recruitment
A	282	2.436	143	13.697	26.80	51%
B	292		218		14.51	74%

Table 3: *Internal Oblique muscle activity in Group-A and Group-B.*

Group	Pre Test Score	Unpaired t – test (2.093)	Post Test Score	Independent t – test (2.093)	Paired t – test (2.262)	% of recruitment
A	255	2.916	143	9.028	16.54	56%
B	272		197		12.67	72%

Table 4: *External Oblique muscle activity in Group-A and Group-B.*

Discussion

There was significant difference found in the EMG data in abdominal muscle activity (Figure 3) between performing constant location and changing location exercise on the Swiss ball (Table 5). Upper rectus abdominis muscle EMG signal was sig¬nificantly greater with all remaining muscles, and significantly less EMG signal with External Oblique com¬pared to all other muscles in constant location exercise. Upper and Lower rectus abdominis muscle EMG signal was sig¬nificantly greater with all remaining muscles, and significantly less EMG signal with Internal Oblique com¬pared to all other muscles in changing location exercise.

Sr. No	Exercise	Upper Rectus Abdominus	Lower Rectus Abdominus	External Oblique	Internal Oblique
1	Constant Location Exercises	62 (20)	60 (14)	51 (12)	56 (12)
2	Changing Location Exercises	74 (31)	73 (19)	74 (12)	72 (13)

Table 5: *Mean (SD) EMG for Each Muscle and Exercise Expressed as a % of Each Muscle's MVIC.*

Upper rectus abdominis EMG signal was significantly greater with the changing location exercise compared to constant location ex¬ercises. Lower rectus abdominis EMG signal was significantly greater with the changing location exercise compared to constant location ex¬ercises. External Oblique EMG signal was significantly greater with the changing location exercise compared to constant location ex¬ercises. Internal Oblique EMG signal was significantly greater with the changing location exercise compared to constant location ex¬ercises. Graphical representations of upper rec¬tus abdominis, lower rectus abdominis, external oblique, and internal oblique EMG signals, among constant and changing location exercises are shown in figures 3,4 and the relative intensities of the exercises with respect to abdominal mus¬cle recruitment are shown in (Table 6).

Sr. No	Muscles Worked / Activity	Very High > 60% MVIC	High 41 - 60% MVIC	Moderate 21 - 40% MVIC	Low 0 - 20% MVIC
1	Upper Rectus Abdominus	Constant Location Changing Location	Nil	Nil	Nil
2	Lower Rectus Abdominus	Changing Location	Constant Location	Nil	Nil
3	External Oblique	Changing Location	Constant Location	Nil	Nil
4	Internal Oblique	Changing Location	Constant Location	Nil	Nil

Table 6: *Relative Abdominal Muscle recruitment.*

To help classify low to high muscle activities from tables 5 and 6 , 0% to 20% MVIC was considered low muscle activity, 21% to 40% MVIC was considered moderate muscle activity, 41% to 60% MVIC was considered high muscle activity, and greater than 60% MVIC was considered very high muscle activity [9]. The exercises that generated muscle activity greater than 60% MVIC may be more conducive to developing muscular strength for that muscle, while the exercises that resulted in muscle activity less than 20% MVIC may be more conducive to developing muscular endurance for that muscle, assuming repeated contractions occur (typically greater than 12 consecutive repetitions is desired for muscular endurance) [10].

Constant location Exercises

The relatively high abdominal muscle activity during the constant location exercises compared to the Maximum voluntary Isometric Contraction (MVIC) suggests that these exercises are good alternatives to traditional abdominal exercises for abdominal muscle recruitment. Moreover, these exercises may be beneficial for individuals with limited workout time and whose goal is to perform exercises that not only provide an abdominal workout but also an upper and lower extremity workout. These exercises may also achieve a great¬er energy expenditure compared to the traditional abdominal exercises because of the greater number of muscles recruited, and relatively high muscular activity, and this should be the focus of future research. Moreover according to the percentage of MVIC Upper rectus abdominus is recruited for 74% of MVIC, Lower rectus abdominus is recruited for 73% of MVIC, External oblique is recruited 74% of MVIC and Internal oblique is recruited about 72% of MVIC.

Changing location Exercises

The changing location Swiss ball exercises produced more amounts of rectus abdominis and external and in¬ternal oblique activity compared to the constant location Swiss ball exercises. Several studies have re¬ported similar or greater amounts of ab¬dominal muscle activity when push-up exercises are performed on an unstable surface (eg, Swiss ball) compared to a flat stable surface [10]. Therefore, changing location Swiss ball exercises performed in the current study can be effective exercises in recruiting upper and lower rectus abdominis, inter¬nal and external oblique muscles. In Changing location exercise Upper rectus abdominus is recruited for 62% of MVIC, Lower rectus abdominus is recruited for 60% of MVIC, External oblique is recruited 51% of MVIC and Internal oblique is recruited about 56% of MVIC.

Limitations

Internal oblique is deep to the external oblique; it is potentially susceptible to considerable EMG cross talk from the external oblique. Relating the EMG amplitude with mus¬cle force and strength during dynamic exercises, as eccentric muscle actions can result in lower activity but higher force, while concentric muscle actions can result in higher muscle activity but lower force.

Conclusion

The results shows that the changing location exercise is the most effective exercise in recruiting the abdominal mus¬cles compared to constant location exercise in chronic low back pain patients.

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