EFFECT OF LUMBAR STABILIZATION EXERCISES VERSUS PRESSURE FEEDBACK TRAINING IN LOW BACK ACHE PATIENTS

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Abstract:
Chronic low back pain is the most common complaints in the urban society causing to absent from the work and activity limitation. Its health, social and economic burden is hefty. Despite developments in modern medicine in general and growing knowledge of spinal diseases, problem of nonspecific low back pain remains unsolved. Although the nonspecific types of bach pain affects approximately 85% of patients while 40% of low back pain patients worry that pain affects their work ability and will make them cripple, or that it underlies some serious disese (Waddell 1998). Even though there is ample evidence stating the efficacy of core stability training but not able to find any study which has compared Pressure Biofeedback training with Core Stability Training in the treatment of chronic low back pain. The aim of the present study was to compare the effectiveness of stabilizer pressure biofeedback training and core stability exercises on pain perception as measure by visual analogue scale in chronic low back pain patients.

Key Words: Back pain, core stability training, stabilizer pressure biofeedback

Introduction

Chronic low back pain is the most common complaints in the urban society causing to absent from the work and activity limitation. Its health, social and economic burden is hefty. If we look to western societies, it has one of the most human suffering, disabling and enormous economic consequences with the frequent use of medical consultation and visit to rehabilitation unit. It is estimated that 70%-80% of population of United States of America is bear on back pain at one point in their life time.[1] It is 2nd most frequent reason for visit to the physician and 5th ranking cause of hospital admission.[2-3] In the United Kingdom back pain is the largest single reason of absence from work in 1988-1989 and is responsible for approximately 12.5% of all sick days.[4]

Despite developments in modern medicine in general and growing knowledge of spinal diseases, the problem of nonspecific low back pain remains unsolved, although the nonspecific type affects approximately 85% of patients reporting any back pain. Approximately 40% of low back pain patients worry that pain affects their work ability, that it will cripple them, or that it underlies some serious disease. Better understanding of multidimensional aspects has widened our concept of low back pain.

There are several causes of low back pain. In a mechanical model, research has implicated pain sensitive vertebral structure such as the intervertebral disc and the zygoapophyseal joints as potential sources of low back pain. Irrespective of the actual source of symptoms, it has been shown that muscles are adversely affected secondary to low back pain. This phenomenon is accepted at peripheral joints such as the knee. For example, irrespective of the knee structure which is injured, e.g. meniscus or ligament, it is commonly accepted that quadriceps function will be adversely affected. Possible neurophysiological mechanisms include pain and reflex inhibition. Muscle re-education is therefore a commonly used intervention in the rehabilitation process, and for many years exercise has been advocated in the treatment of low back pain. Many researchers have focussed on issues of muscle strength. The basis for this focus is the premise that strong abdominal and back muscles are able to provide support for the lumbar spine.[5]

Despite the common acceptance of this principle, systematic reviews have not on the whole supported general trunk muscle strengthening programs.[6] This has led to the development of specific exercise programs designed to protect and support the damaged joints and allow healing of the injured tissues.[7,8] Muscles can be broadly divided into two categories, local and global muscles.[9] The local muscle system includes deep muscles that are attached to the lumber vertebrae and are capable of directly controlling the stiffness of the lumbar segments.[10] In contrast, the global muscle system encompasses larger and more superficial muscles of the trunk. Their role is to move the spine and to control larger external loads, which occur with normal daily function. Biomechanical research has demonstrated that deep, local muscles are important for controlling, protecting and supporting the joints. The muscles of the local synergy, which are important for the lumbo-pelvic region include the segmental lumbar multifidus, the transverses abdominis, the pelvic f loor and the diaphragm. There is evidence that low back pain results in an alteration in function of the local muscles, which lose their protective role.[8,10,11]

A common clinical finding in low back pain patients is decreased range of motion of the spine with increased paraspinal activity. Disturbances in neuromuscular control have also been frequently connected with chronic low back pain and considered a possible linkage between pain and disability[12]. These impaired functions recover with treatment or active rehabilitation. Spinal manipulative therapy is commonly recommended for low back pain, although previous systematic reviews and practice guidelines have produced discordant findings as to the effectiveness of this therapy. A recent focus in the management of chronic low back pain patients has been the specific training of the deep abdominal (internal oblique and transversus abdominis) and lumbar multifidus muscles. The primary role of these muscles is considered to be the provision of dynamic stability and segmental control of the spine. For the treatment of chronic low back pain with radiological diagnosis of spondylolysis or spondylolisthesis, one randomized controlled trial of specific stabilizing exercises showed significant and longer-lasting reduction in pain intensity and functional disability levels than did other commonly prescribed conservative treatment programs.

Investigators have reported that individuals with back pain may have motor control deficits or errors that affect their ability to engage the muscles that stabilize the spine. Maintaining segmental control within the trunk contributes to spinal stability and reduces unnecessary movement intersegmentally. This can serve to decrease the risk of back pain by causing a reduction in tissue strain, deformation, compression, and overstretching. Clinicians maintain that the mechanisms involved in spinal stability can be linked to differences in the function of the trunk muscles[13]. The trunk muscles have been classified into 2 categories, and each one performs distinct functions. The first category is the global muscle system. The muscles in this category are larger and more superficial in comparison to other muscles. The global muscles act to transfer loads and move the spinal column as a whole. Examples include the rectus abdominis and the external oblique[14].

The second category is the local muscle system. The local muscles are smaller and deeper than the global muscles. They are intersegmental and produce only small amounts of force. Local muscles aid in proprioception and postural control, which can decrease the risk of injury. The local muscles also contribute to maintaining stiffness along the spinal column. The multifidus and the transverse abdominis are two examples[15].

A number of investigators have cited evidence that supports the use of stabilization exercises for enhancing spinal stability[20]. The local muscles are said to be crucial in this mechanism. This may be because of their contribution to maintaining the position of the spine and their ability to improve trunk endurance. Core stability training is frequently used to improve spinal stability. It has been used for many years in physical therapy and has become popular in fitness settings[17]. It has been speculated that this method of training improves spinal stability and may assist in decreasing the risk of back pain.

Studies that have been done on core stability training demonstrate promise for its effects on the musculature of the trunk[18]. However, previous investigations have not been designed to explore the involvement of the local muscles, which act to stabilize the spine. In addition, the methods of analysis have typically stressed the global muscles through assessments for strength or surface EMG recordings. These measures may not adequately identify improvements in spinal stability brought on by the local muscles. Core stability training that focuses on exercises with a neutral spine may be appropriate for targeting the specific function of the local muscles during the early phases of programming for improving spinal stability[19-20].

Even though there is ample evidence stating the efficacy of core stability training I was unable find any study which has compared Pressure Biofeedback training with Core Stability Training in the treatment of chronic low back pain. The aim of the present study was to compare the effectiveness of Stabilizer Pressure Biofeedback Training and Core Stability Exercises on pain perception as measure by visual analogue scale in chronic low back pain patients.

Methodology

A total of 30 subjects were selected for the study on the basis of inclusion and exclusion criteria. The subjects were randomly assigned to Group 1and Group 2 each comprising 15 subjects. All the patients were recruited from the inpatient outpatient department Government Civil Hospital, Ahmadabad. Only those patients were included who were between 40-60 years of age, presented with chronic nonspecific recurrent low back pain. The duration of the symptoms was diagnosed as sub-acute and chronic according to the IASP classification of pain. Those patients who were having severe or excruciating pain, radiating pain to the legs, history of fracture, surgery, or constitutional symptoms like fever, malaise, etc indicating infection, any inflammatory conditions, radiographic changes showing cervical spinal malformations, osteoporosis, bony abnormalities, scoliotic or kyphotic spine, pregnancy, sensory impairments, vascular causes of radiating pain or neoplasms were excluded. The above stated conditions were ruled out on the discretion of a medical professional.

Study Design

The study was designed as a two group pre-test and post-test longitudinal study. Pain and Functional Disability were taken as outcome measure for this study. The experimental design included a pre-test measure of the dependent variables Pain and Disability and after 4 weeks of treatment the dependent variables were measured again. Visual Analouge Scale was used for measuring pain and Oswestry Disability Questionnaire for finding level of functional disability.

All the selected subjects were informed in detail about the type and nature of the study and were made to sign the informed consent. After taking down the demographic data the visual analogue scale and Disability scores were noted down. Then the subjects in both the groups were made to do common warm-up exercises initially. These exercises include light aerobic work in the form of exercise on bicycle for 5 minutes at moderate pace or jogging for 10 minutes.

Group 1: Core Stability Training

Core stabilization refers to the muscles that act to stabilize the lumbar spine and lumbopelvic and hip complex as well as muscles acting to control position of the head, arms, and trunk segment relative to the body's base of support.[41]

All the subjects in the Group 1 had undergone one month core stability training which comprises of exercises aimed at increasing spinal stability. Isolated Lumbar stabilizing muscles training: Development of the perception of the isolated isometric specific contraction of the stabilizing muscles.

Group 2: Stabilizer Bio-feedback training

The Stabilizer is a simple device which registers changing pressure in an air filled pressure cell. This allows body movement, especially spinal movement, to be detected during exercise. The unit consists of a combined gauge/inflation bulb connected to a pressure cell. The Stabilizer is used to monitor and provide feedback on body movement during exercise. The three-chamber pressure cell of the Stabilizer was placed between the part of the body and floor. It was inflated till it molds between the body part and the supporting surface. A pressure of 40 mmHg was maintained as the resting pressure of the inflated cell. Changes in body weight on the cell on any of the three compartments will register a pressure change on the gauge.

The Stabilizer biofeedback training was given for 6 days a week for four weeks. This maneuver was repeated for all the muscles responsible for lumbar spinal stability. All the activities were performed in three sets of 10 repetitions each. Each training session comprises of 45 mins.

Results

Thirty subjects, 23 males and 7 females were randomly divided into two groups; group 1 and group 2.

Table 1: Demographic Characteristics of Subjects in both the groups

Group	Visual Analogue Scale Score (n=15)		
	Baseline	After 15 Days	After 30 days
Core Stability Exercise	6.7±1	4.6±1.7	2.3±1.7
Pressure Biofeedback	6.2±1.7	3.5±1.8	0.9±1
Group	Oswestry Disability Index Score (n=15)		
	Baseline	Baseline	Baseline
Core Stability Exercise	40.4±12.5	30.6±12.6	19.8±14
Pressure Biofeedback	46.6±21	24.8±18	5.1 ± 6

Fifteen subjects were taken in each group, with a mean age and standard deviation of subjects in group 1 and 2 were 23.4±1.95 and 21.66±1.95 respectively. There were 12 males and 3 females in group1 and 11 males and 4 females in group2. Statistical analysis revealed no statistically significant differences between the groups during the baseline readings.

The outcome measures were pain, measured on Visual Analogue Scale and functional disability measured by Oswestry Disability Index. All the measurement was taken on the 1st day, 15th day and after completion of the training on 30th day. All the data were compared for both the within group and between group anlysis using repeated measure ANOVA.

Effect of Training on Pain and Disability: Assessment of improvement in this experiment included two dependent variables; Visual Analog Scale (VAS) score and Oswestry Disability Index/Questionnaire Score (ODI). One-way MANOVA demonstrated a significant improvement in visual analogue scale and ODI among the three readings taken after 1st, 15th and 30th day respectively. Further analysis was performed to determine the difference in dependent variables between both the groups a post hoc analysis was performed using Bonferroni test. In Group1 it was found that there was a significant difference for visual analogue scale (F = 33.29, P=0.001), and ODI (F= 73.19, P=0.001) among all three readings. In Group 2 also it was found out that there was a significant difference for visual analogue scale (F=20.79, P=0.001) and ODI (F= 32.56, P=0.001) between the three readings. Results are presented in the following sections. (Table 5.2)

Effect of Core Stability Exercises on Pain and Disability: The group1 getting Core Stability Training has shown significant improvement in terms of decrease in pain and functional disability. The one month Core Stability Training brought 66% decrease in pain and 25% improvement on Oswestry Disability Index.

Even after 15 days of training there was a positive effect of this training which improved further with four weeks of training. Post Hoc analysis has shown that there was a significant improvement in baseline readings of visual analogue scale and ODI when the comparison was made between 1st and 15th day, 1st and 30th day and 15th and 30th.

Effect of Stabilizer Bio-Feedback Training on Pain and Disability: In Group2 also a similar improvement was seen as with the Group1. There was a significant decrease among the baseline reading measured on 1st day and the consequent readings taken on 15th and 30th day. Post hoc analysis has shown that there was improvement in pain and disability score with the training which was found statistically significant.

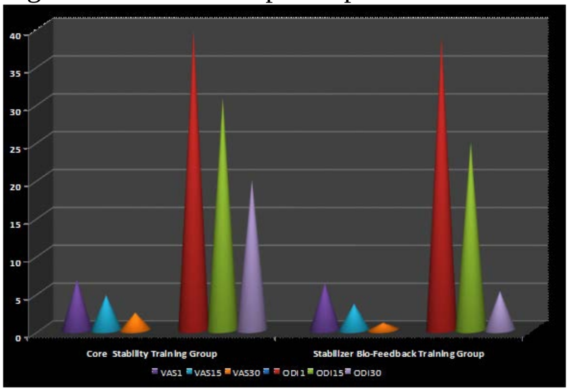
Table 2: Repeated Measure ANOVA for visual analogue scale and ODI

			Group1 (n=15)	Group2 (n=15)
Visual Analogue Scale	Day 1	M ± SD	6.69±0.9	6.2±1.7
	Day 15	M ± SD	4.6±1.7	3.46±1.8
	Day 30	M ± SD	2.27±1.7	0.94±1
	RANOVA	F	33.29	73.19
		P	0.001	0.001
	Post-Hoc Analysis (P=)	1vs15	0	0.001
		15vs30	0.002	0.001
		1vs30	0.00	0.00
Oswestry Disability Index	Day 1	M ± SD	40.4±12.5	46.6±21.2
	Day 15	M ± SD	30.6±12.6	24±18.2
	Day 30	M ± SD	19.8±14.6	5.13±6.1
	RANOVA	F	20.79	32.56
		P	0.001	0.001
	Post-Hoc Analysis (P=)	1vs15	0.003	0.003
		15vs30	0.003	0.003
		1vs30	0.00	0.oo

Between Group Analysis

To find out, how both the groups have behaved in terms of improvement and to test the experimental hypothesis, a between group analysis was performed using independent t-test for all the variables. The findings suggested that the group getting Stabilizer Bio-feedback training have shown comparatively more improvement on both Visual Analogue Scale and Oswestry Disability Index.

Figure 1: Within Group Comparison of VAS and ODI



The result shows that for initial two weeks treatment both the group behaved similarly and improvement in pain and functional disability was seen in both the groups.

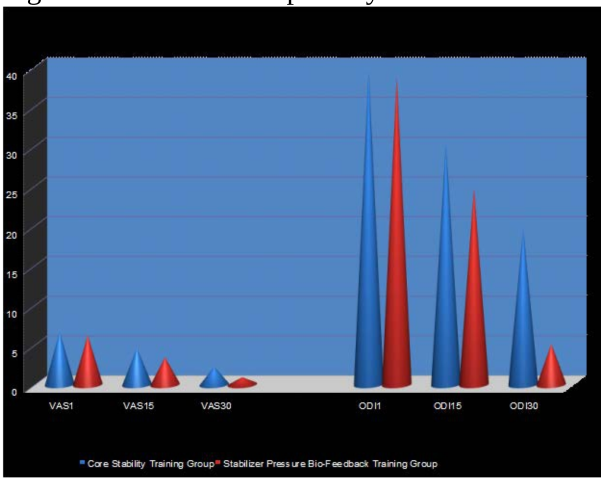
Table 3: Between group analysis of visual analogue scale and ODI among all three conditions.

Varia bles	Group 1 (n=15) M ± SD	Group2 (n=15) M ± SD	t-test t	p
VAS1	6.7±0.9	6.2±1.7	0.903	0.374**
VAS 15	4.6±1.7	3.5±1.8	1.738	0.093**

VAS 30	2.3±1.7	0.9±1	2.585	0.015*
ODI 1	39.7±12.5	38.8±16.2	0.176	0.861**
ODI 15	30.6±12.6	24.8±14	1.016	0.381**
ODI 30	19.8±14	5.1±6.1	28	0.001*

As evident by the results there was no statistically significant difference between the group getting Core Stability Training or Stabilizer Pressure Bio-Feedback Training at 1st day (VAS: t =0.903, p=0.374 ODI: t =0.176, p=0.861) or after 15 days of treatment (VAS: t =1.738, p=0.093 ODI: t =1.016, p=0.381). But after four weeks of treatment the result shows a statistically significant difference between both the groups and also it shows that the group getting Stabilizer Bio-Feedback training improved better on both the scales Visual Analogue Scale as well as Oswestry Disability Scale.

Figure 2: Between Group Analysis of the VAS and ODI



The results of this study support the initial hypothesis that Stabilizer Pressure Biofeedback training of the "stability" muscles of the trunk is more effective in reducing pain and functional disability in patients with chronic low back pain. Analysis of the pain and functional disability score data in the experimental group revealed that this treatment approach was more effective than the Core Stability Training. These findings support the Punjabi's[21] hypothesis that the stability of the lumbar spine is dependent not solely on the basic morphology of the spine, but also the correct functioning of the neuromuscular system. Also, Radebold A.[22] stated that muscle recruitment and timing pattern play an important role in maintaining lumbar spine stability. Therefore, exercises specifying the isolated contraction of multifidus muscle were incorporated in the Group2, in contrast to the core stability exercises in the group1. Hence, it gets clearer that the significantly better results in the group1 are due to the proper recruitment of the specific back muscles, which was facilitated by the Stabilizer. Hodges and Richardson[19] showed that the co-contraction of the transverse abdominis and multifidus muscles occurred prior to any movement of the limbs. They also showed that the timing of coordination of these muscles was very significant, and that back injury patients were unable to recruit their transverse abdominis and multifidus muscles early enough to stabilise the spine prior to movement. It hence makes it utmost important to strengthen these deep and local muscles to uproot the low back aches completely and maintains segmental stability. Therefore, it can be safely stated that in the present study, the group in which this was emphasized showed a significant improvement in terms of pain and functional ability in comparison to the other group, as evident in the result section.

By definition, the deep-trunk muscles act as 'stabilizers' and are not involved in producing movements, but instead use static or isometric contractions. Furthermore, they must act as stabilisers continuously during everyday activities as well as sport, and so require very good endurance of low-level forces. Muscle impairments are not more of strength but rather problems in motor control. This is what was kept in mind while planning the exercise regime of the group1, which enhanced the spinal segmental support and control. The subjects were trained to selectively contract the stabilizers by the help of stabilizer biofeedback and later worked on improving the endurance in terms of static control. This form of specific training at low levels of activation supports the recent findings of Cholewicke and McGill[24] that only low levels of maximal voluntary contraction of the segmental muscles are required to ensure the stability of the spine in vivo. It is also consistent with assertion that motor learning and control are not simply a process of strength training, but depend on patterning and inhibition of motor neurons, with the acquisition of skills occurring through selective inhibition of unnecessary muscular activity, as well as the activation of additional motor units.

Further, Shaughnessy M[25] in a pilot study discovered that program of lumbar stabilization is effective in improving quality of life and functional outcome in patients with chronic low back pain. A similar study conducted by Cholewicke and McGill[11] revealed that lumbar stability is maintained in vivo by increasing the activity (stiffness) of the lumbar segmental muscles, and highlighted the importance of motor control to coordinate muscle recruitment between large trunk muscle and small intrinsic muscles during functional activities, to ensure stability is maintained. This concept when merged with that of Bergmark,[25] specifying the classification of trunk muscles into local and global muscles, has overemphasized the need to train the deep muscles of the back to provide segmental stability while directly controlling the lumbar segments. The present study on segmental stabilisation has incorporated all these theories and has come out with an exercise regimen working directly at the deep stabiliser muscles. The positive result with a significant difference in terms of pain and functional ability thus supports the hypotheses put forth by eminent researchers as stated above.

In addition to this, Tesh K M[26] has also suggested that the muscles of the antero-lateral abdominal wall increase the stability of the lumbar region of the vertebral column by tensing the thoracolumbar fascia and by raising intra-abdominal pressure. Of the back extensor muscles, the lumbar muscles is considered to have the greatest potential to provide dynamic control to the motion segment, in its neutral zone. This study was considered important on account of the fact that patients of chronic low back pain would always seek not only a relief from pain but also the ability to perform ADL without discomfort. Hence, the patients need to be trained not only for the static control but also dynamic functional independence. With this view in mind, the exercises focused on the appropriate strengthening of the deep back muscles such that it can lead to alleviation of pain during motor tasks as well, thus aiming at complete recovery.

The most significant finding of the present study was the sustained reduction in symptoms and functional disability levels in the experimental groups at the 15th and 30th day follow up. The findings of this study support the view that a change in the motor program had occurred in both the group after the intervention, such that the automatic pattern of recruitment of the abdominals to stabilize the spine during a motor task incorporated higher levels of deep abdominal muscle activity. This appears to represent an enhanced ability, in those in the experimental group, to stabilize dynamically their spine during functional tasks. Hence it can very well be stated that stabilization exercises do appear to provide additional benefits to patients with sub acute or chronic low back pain who have no clinical signs suggesting the presence of spinal instability. Therefore, such population of chronic low back pain patients must be identified and treated with specific stabilizing exercise intervention based on motor control and motor learning in order to achieve efficient relief of excessive load from the spine, to enhance segmental stabilization and to control pain in a functional manner.

Future Research

The significant difference in results observe in this study suggests the effectiveness of both exercise regimes, but also suggests the need for a more comprehensive research for future including patients with gross instability (evident radiologically) and side-to-side differences while administering stabilization exercises. Other factors such as role of age, gender, duration of study etc. may also be included in the future studies. Use of sophisticated devices such as electromyography biofeedback units, or real time ultrasound scanners might have made this study more sensitive in terms of generalization of results.

Relevance to Clinical Practice

Since EMG was not used in this study, the results observed in this study suggest the cost effectiveness in assessing pain and disability as would be required in clinical settings (devoid of EMG and other sophisticated equipments to assess level of muscle imbalance). There are studies stating the use of exercise regimes only (without electrotherapeutic modalities) in which patients have benefited and thus the exclusion of these does not pose to be unethical. Also, since no other modality was used, it is a cost–effective method of treatment, as would be preferred in clinical settings.

Limitations

- The long term effect of the study could not be established due to lack of follow up on pain and disability, after the thirty days of treatment.
- The home care programme taught to the patients could not be done under direct supervision.
- Apart from the clinical physical therapist palpating the transversus abdominis and multifidus muscle contraction in the subjects, there was no other means of verifying whether these muscles were recruited appropriately.

Conclusion

The findings of this trial support the view that the functional integration of Stabilizer Bio-feedback training directed at the deep abdominals and the lumbar muscles are effective in reducing pain and functional disability in patients with chronic low back pain. This supports Punjabi's hypothesis, that spinal stability is dependent on an inter play between the passive, active, and neural control systems. Specific training of the muscles considered to provide dynamics stability to the lumbar spine may act to maintain the neutral zones of the motions segment within more normal limits during functional activity. In addition, the results of this study indicate that a "Stabilizer Bio-Feedback" treatment approach directed at specific muscles activation is more effective than Core Stability Training commonly used in patients with chronic low back pain.

References:

1. Anderson GBJ. Epidemiology features of chronic low back pain.*Lancet* 1999; 354: 581-585
2. Taylor VM, Deyo RA, Cherkin DC, Keuter W. Low back pain hospitalization: recent United States trends and regional variation. *Spine* 1994; 19: 1207-1213

3.Hart LG, Deyo RA, Cherkin DC. Physician office visits for low back pain. Frequency, clinical evaluation, and treatment patterns from a U.S. national survey. *Spine* 1995; 20: 11-19.pko;l./

3. Frank A. Low back pain. *BMJ* 1993; 306: 901-909
4. Koes B, Bouter L, Beckerman H Physiotherapy Exercises and Back Pain: a blinded review, British Medical Journal 1991; 302: 1572-1576.
5. Richardson CA, Jull GA Muscle control – pain control. What exercises would you prescribe? Manual Therapy 1995; 1: 2-10.
6. Richardson C, Jull G, Hodges P, et al; Therapeutic Exercise for Spinal Segmental Stabilization in Low Back Pain – Scientific Basis and Clinical Approach. Churchill Livingstone, Edinburgh. 1999.
7. Bergmark A Stability of the lumbar spine. A study in mechanical engineering. Acta Orthopaedica Scandinavica 1989; 230(Suppl): 20-24.
8. Hides JA, Richardson CA, Jull GA Multifidus muscle recovery is not automatic following resolution of acute first episode low pack pain. Spine 1996; 21: 2763-2769.
9. Hodges PW, Richardson CA Inefficient muscular stabilisation of the abdominis. Spine 1996; 21: 2640-2650.
10. Richardson CA, Snijders CJ, Hides JA, et al; The relationship between the transversely oriented abdominal muscles, sacroiliac joint mechanics and low back pain. Spine 2002; 27(4):399-405.
11. Hodges, P. and Moseley, L., Pain and motor control of the lumbopelvic region: effect andpossible mechanisms, J Electromyogr Kinesiol, 13 (2003) 361-70.
12. Hodges, P.W., B.P. Hons, and C. Richardson. Inefficient muscular stabilization of the lumbar spine associated with low back pain: A motor control evaluation of transversus abdominis. Spine 21:2640–2650. 1996.
13. Nichols, J.F., D. Medina, and E. Dean. Effects of strength, balance, and trunk stabilization training on measures of functionalfitness in older adults. Am. J. Med. Sports 3:279–285.2001.
14. Richardson, C.A., and G.A. Jull. Muscle control—pain control: What exercises would you prescribe? Man. Ther. 1:2–10.1995

15. Richardson, C., G. Jull, P. Hodges, and J. Hides. Therapeutic Exercise for Spinal Segmental Stabilization in Low Back Pain: Scientific Basis and Clinical Approach. Edinburgh, Scotland: Churchill Livingstone, 1999.
16. Mc Gills, S.M. Low back exercises: Evidence for improving exercise regimens. Phys. Ther. 78:754–765. 1998.
17. O'sullivan, P.B., G.D.M. Phyty, L.T. Twomey, and G.T. Allison. Evaluation of specific stabilizing exercise in the treatment of chronic low back pain with radiologic diagnosis of spondylolysis or spondylolisthesis. Spine 22:2959–2967. 1997.
18. Stanton, R., P.R. Reaburn, and B. Humphries. The effect of short-term Swiss ball training on core stability and running economy. J. Strength Cond. Res. 18:522–528. 2004.
19. Mcgill, S., A. Childs, and C. Liebenson. Endurance times for low back stabilization exercises: Clinical targets for testing and training from a normal database. Arch. Phys. Med. Rehabil. 80:941–944. 1999.
20. Radebold A,Cholwicki J, PasnjabiMM, et al. Muscle response pattern to sudden trunk loading in healthy individuals and in patients with chronic low back pain. Spine 2000;25;947-54
21. Richardson CA, Jull GA, Hodges P Hides . Therapeutic exercise for spinal segmental stabilization in low back pain scientific basis and clinical approach, Edinburgh, Churchill Livingstine ,1999
22. Cholewicki J, Mc G ill SM. Mechanical stability of the in vivo lumbar spine: implications for injury and chronic low back pain. Clin Biomech 1996; 11: 1-15.
23. Shaughnessy M, Caulfield B. Apilot study to investigate the effect of lumbar stabilization exercise training on functional ability and quality of life in patients with chronic low back pain. Int J Rehab Res. 2004 Dec;7(4):297-301.
24. Bergmark A . Stability of the lumbar spine. Acta Orthop Scand 1989;60:1-54.
25. Tesh KM, Dunn JS, Evans JH.The abdominal muscles and vertebral stability. Spine. 1987 Jun;12(5):501-8.