대한정형물리치료학회지 2000.
제6권 제1호.
The Journal of Korean Academy of Orthopaedic Manual Physical Therapy
2000. Vol. 6, No. 1.

The Spinal Flexibility and Response Time of Erector Spinae Muscle Following Stabilization Exercise

Department of Physical Therapy, Clarke College, Dubuque, IA, USA

Paul S. Sung, PT, Ph.D.

만성 요통 환자에서 척추 유연성과 허리 근육 반응속도 분석

미국 아이오와주 클락대학교 대학원 물리치료학과 교수
성 수 원

-국문 요약-

허리 근육손상은 기대치 못한 상황에서 신체의 적절한 반응이 지연될 경우 근육 염좌와 같은 상해나 요통으로 연결된다. 이 연구는 척추 안정 운동 후 척추의 유연성과 척추 근육의 반응 속도를 만성 요통 환자와 정상인을 대상으로 비교 연구 하였다. 만성 요통 환자 군은 척추 안정 운동을 4주간 20회 시행하였으며 이와 비슷한 특성을 가진 대조군을 비교하였다. 신체 유연성은 환자가 앉은 자세에서 척추를 축으로 신체의 회전 정도를 측정하였다. 척추 반응 속도 측정은 환자가 선 자세에서 두 손으로 판을 들고있는 동안 정구공이 1.8 m (6.4 N) 에서 낙하시 좌, 우측 척추 근육의 반응 속도를 Wavelet 분석으로 측정하였다. 연구 결과 척추 안정 운동을 행한 만성 요통 환자군의 신체 유연성과 척추 근육 반응 속도가 통계적으로 유의하게 증가하였다. 척추 유연성은 만성 요통 환자 군에서 131.0cm에서 척추안정 운동후 144.1cm으로 증가하였다 ($p<0.05$). 척추 근육 반응 속도는 척추 안정 운동을 행한 만성 요통 환자 군에서 90.00msec에서 68.55msec로 ($p<0.05$), 정상 군에서는 86.28msec에서 75.64msec로 ($p>0.05$) 단축되었다. 척추 안정 운동은 근, 신경 조직의 반응속도를 증가시키며 특히 만성 요통 환자에서 척추의 안정성을 회복시킨다. 특히 척추의 안정성 증가는 기대치 못한 상황에서 신체의 적절한 반응의 속도를 회복시키며 결과적으로 허리 손상을 예방 할 수 있다. 물리치료학에서 근 골격 신경계의 반응 속도측정을 위한 연구로 Wavelet 분석과 같은 첨단장비를 통한 운동 치료의 질에 관한 연구의 도입이 필요하다. 또한 구체적인 치료적 운동결과의 측정을 통해 물리 치료의 효과성과 효율성을 높이기 위한 생체 의학적 연구가 요망된다.

Back injuries are very common in our society (Lavender, 1989, Oxland, 1992). The cause of most back injuries is unknown. However, one of the most related injuries is the mechanical factor, which causes an increase in the risk of recurrence of low back pain and dysfunction (LBD). The mechanical factors included sudden loading incidents, such as slips, trips and falls as well as bending and twisting while lifting (Kelsey, 1984). These factors cause an increase in the risk of recurrence of low back pain and dysfunction (LBD).

There is a growing scientific basis supporting active rehabilitation programs as an effective means of achieving lasting relief of pain and disability in the chronic LBD population (Waddell, 1995). Treatment approaches for chronic LBD are based on reversing and preventing the recurrence of impairments of the musculoskeletal system, with the expectation that such changes will lead to improved function and reduced disability (Jette, 1995). In addition, physical therapists have always advocated and respected patient-level goals, as reflected in the traditional emphasis on maximizing patient function (Sung, 1999).

The treatment of LBD remains controversial today, especially because of those who have not recovered from an acute bout of LBD after two months will go on to become chronic sufferers (Klenerman, 1995). It has been suggested that 85% of chronic LBD patients do not have a definite pathoanatomical or patho-physiological basis to their pain. On this basis, it has been argued that improved function should be the goal for patients with LBD (Teassel, 1996).

Specific exercise approaches for the management of LBD have been advocated by number of authors (Abenhaim, 2000). However, few clinical trials have evaluated their benefits in the LBD population (Richardson, 1995). No clinical evidence is yet available as to the effectiveness of a spinal stabilization exercise for the treatment of chronic LBD.

It is necessary to consider enhancing functional outcomes based on neurophysiological research linking lumbar joint stability and delay of response time following therapeutic exercises. Postural correction can be achieved by strengthening the muscles of the spine (Abenhaim, 2000). However, strengthening exercises will not educate muscles to maintain the correct posture. Actively maintaining the correct posture is the only way known to achieve postural correction. The muscles required to maintain this position are automatically strengthened merely by performing the task for which they were originally designed (McKenzie, 1981).

Most of LBD, related to unexpected injurious events, may be measured by the response of back muscles to the jarring action produced (Wilder, 1996). If risk factors, such as delayed muscular response time, can be identified, interventions and exercise programs, such as stabilization exercises, could be generated and possibly decrease the incidence of LBD.

Spinal stabilization exercise, especially in relation to the neuromuscular system, plays a key clinical role in the treatment of subjects with chronic LBD (O' Sullivan, 1997). This exercise has become an integral component of treatment and has been useful in improving LBD. They involve the co-contraction of muscles to restore stability to the spine and protect it from biomechanical stresses and further injuries (Saal, 1991). These exercises focus on improving the dynamic stability of the spine. In addition, the neuromuscular system may be capable of restoring segmental spinal stability to a motion segment after injury (Panjabi, 1992, Wilder, 1988).

Also, the spinal stabilization exercise approach integrating deep muscle co-contraction into dynamic function. The use of light functional tasks allows deep muscle support to be trained during activities while moving trunk through movement directions that usually aggravate the pain. For example, the multifidus muscle maintain the normal lumbosacral curve during any exercise (Aspden, 1989). The functional improvement with the spinal stabilization exercise needs to be clarified whether the exercise incorporates motor skill into functional tasks especially, the spinal flexibility and response time.

The primary purpose of the study was to investigate the effect of a specific stabilizing exercise in subjects with and without chronic LBD. This study was to determine whether the erector spinae muscle could be selectively trained to contract preferentially during activities where the global muscles are moving the lumbopelvic region especially in the response to unexpected events.

More specifically, two hypotheses were tested in this study. Following a four-week spinal stabilizing exercise program, subjects with chronic LBD will be more like the normal control group than they were before the program by showing a statistically significant :

1. Increased spinal flexibility scores ;
2. Reduced in response time to a sudden load of the erector spinae muscle.

METHODS

Subjects

The subjects were 23 volunteers between the ages of 24 and 70. The average age is 44.04. Participants were recruited from local primary care physicians or on a voluntary basis.

Participants received information regarding the purpose and methods of the study and signed a copy of the consent form. Normal subjects were matched based on the characteristics of LBD. Individuals with LBD were eligible to participate if they : 1) were 21 years of age or older, 2) had chronic LBD (greater than 2 months duration) with or without pain referral into lower extremities ; and 3) indicated willingness to participate in a daily exercise program during the intervention period and participate in supervised exercise sessions three times per week.

Patients were excluded from participation if they : 1) participated in stabilization exercises previously ; 2) had diagnosed psychological illness ; 3) had difficulty in understanding written/spoken English, which precluded them from completing questionnaires ; 4) had diagnosed inflammatory joint disease ; 5) had overt neurological signs (sensory or motor paralysis) ; or 6) were pregnant.

Instrumentation

1. Spinal flexibility

The spinal flexibility test was designed to determine how successful a person can physically move the spine and in identifying objects to the posterior without consideration for the specific impairments that might limit performance (Schenkman, 1995). This was performed as one means of quantifying a patient's combined axial motion, as it would be used in functional context (Figure 1).

2. Muscle response time to sudden load

Sudden loading was accomplished using methods described by Wilder et al (1996). A sudden load was applied by dropping a 6.4 N tennis ball (weighted with lead shot) from a height of approximately 1.8 meters onto an instrument tray held by the standing subject, as shown in Figure 2. The ball fell directly on a load cell, which provided output voltage indicating the precise moment of the strike.

When the weighted ball began to fall, four seconds of data were collected at a rate of 1,024 samples per second from biceps and erector spinae EMG electrodes as well as from the load cell in the instrumented tray. EMG data was collected with differential preamplified silver-silver chloride surface electrode assemblies (Therapeutic Unlimited, Inc., Iowa City, IA). These assemblies provide an interelectrode distance of 20 mm with 8-mm diameter active electrodes and an on-site gain of 35. Signals were further amplified with a GCS 67 amplifier with high input impedance, a common mode rejection ratio of 87 dB at 60 Hz.

The data acquisition system was used AcqKnowledgeR software, a PC based data acquisition system from BIOPAC Systems, Inc.

(Santa Barbara, CA). A recently developed mathematical technique, known as Wavelet analysis, has been successfully applied in analyzing complex non-stationary signals in many scientific fields (Lee, 1998). Wavelet analysis can provide accurate time from trigger point as well as features of the signal. These characteristics of the Wavelet analysis make it a more powerful tool than Fourier methods for surface EMG analysis, by providing an optimum time-frequency resolution (Akay, 1994).

This Wavelet analysis, which greatly smoothed the noisy EMG signal, was simplified without losing the significant features of the signal (Lee, 1998). One example of how this complex EMG signal processing is performed is shown in Figure 3. Below the original signal and the trigger signal is the RMS with 25 ms of moving window. The other three are the linear envelopes processed by low pass filters with cut-off frequency set at 10 Hz, 50 Hz and 250 Hz. The nine numbers, three columns and three rows appearing on the right side of each level are the onset times detected by a combination of different criteria. Three columns, 10 ms, 25 ms, and 50 ms, are the widths of window used to calculate the mean of the EMG activity. The three rows are the standard deviations for comparing the calculated mean activity with the background activity. The bottom four levels show the outcome based on the Wavelet methods. The response time, determined by traditional methods, shows wide variation depending on the method and criteria used. For example, in the RMS (25ms) level, the calculated response time varies from 971 ms to 1036 ms, which is a 65 ms difference. However, the Wavelet methods provided very precise and consistent onset time determination. The response time, noted as delay in Figure 2, varies only ± 2 ms (107-109 ms).

Procedure

Each subject first read and signed the informed consent statement, measurements of spinal flexibility and sudden load response times were then measured as described. Spinal flexibility was measured with a blind procedure. Therefore, the examiner was unable to differentiate between subjects with or without chronic LBD.

The pain group was treated with the spinal stabilization exercise before and after measurements of response time and spinal flexibility. The spinal stabilization exercise approach utilized in this study is commonly advocated in the rehabilitation of chronic LBD patients. The specific exercise intervention represents a motor learning approach to exercise training and helping the subject to learn each step prior to learning the entire task. In this study, the spinal stabilization exercise program consisted of five different types of exercises.

1. Upper body extension : With pillow supporting abdomen, clasp hands behind back and lift body off floor. Keep chin tucked while lifting.
2. Alternate arm and leg lift : Keep knee locked and lift leg 8-10 inches from floor, along with opposite arm.
3. Alternate arm and leg extension on all fours : Raise opposite arm and leg. Do not arch neck.
4. Diagonal curl-up : Keeping arms folded across chest, tilt pelvis to flatten back. Lift head and shoulders from floor while rotating to one side.
5. Curl-up : With arms at sides, tilt pelvis to flatten back. Raise shoulders and head from floor. Use arms to support trunk if necessary. Curl-ups excel at increasing the activity of the rectus abdominis muscle, but they produce relatively smaller oblique muscle activity.

For the sudden load test, the surface EMG electrodes were applied on the skin, which was prepared to reduce skin impedance, as described by Gilmore and Meyers (1983). EMG electrodes were fixed to the skin according to Zipp (1982). They were attached to the right and left paraspinal muscles. The locations for surface electrode leads for selected muscles were based on the distance from the specific muscles' insertion. For example, the electrodes for the paraspinal muscles were placed one sixth of the distance from the iliac crest to the vertebra prominence in cervical spine because that is where the maximum amplitude of action potentials occurs.

The time of the muscle response was measured in terms (msec) of delay between the onset of the sudden load as indicated by the load cell on the tray and the onset of the EMG response of the biceps and paraspinal muscles. The response time of increased EMG activity was accurately determined by use of the Wavelet technique. Aural and visual sensory cues, as to the moment of impact, were masked with a white noise in headphones and a blindfold. Randomizing the movement when the weighted ball was released minimized learning effects. Therefore, the participant was unable to anticipate exactly when the weighted ball would strike the instrumented tray.

Data analysis

To test the hypotheses of the study, spinal flexibility with trunk axial rotation and response time based on the erector spinae muscle were analyzed. An independent t-test was used to analyze the difference of spinal flexibility over time between the pain and normal group. A paired t-test was used to determine the difference of spinal flexibility from pre- and post-test within the pain and normal group. Repeated measure ANOVA was performed to investigate for differences in response time of the erector spinae muscle between the pain and normal group.

Results

1. Spinal flexibility

Flexibility was measured in both the pain and no-pain groups, in both the dominant and non-dominant side of back and both prior to and following treatment. Analysis of the model revealed a significant treatment group and time, and a trend for the rotational direction main effects ($F_{1,21} = 15.01$, $p < .0009$, $F_{1,21} = 19.09$, $p < .0003$, $F_{1,21} = 3.82$, $p < .065$, respectively). In addition, there was a significant treatment and time interaction ($F_{1,21} = 13.45$, $p < .002$). Examination of the means for the rotational direction trend indicated that, across treatment groups and time, there was a trend toward greater flexibility in the non-dominant compared to the dominant-side axial rotation (152.5 ± 18.2 ; 147.8 ± 17.7, $p < .065$). The treatment and time main effects were obscured by the treatment and time interaction, which is illustrated in Figure 4. Follow-up tests of simple effects exploring the two-way interaction indicated that, as would be expected, the pain group was significantly less flexible than the no-pain group at both the pre- (131.0 ± 13.7 vs. 157.6 ± 13.7, $p < .0001$) and post-treatment assessments (144.1 ± 18.7 vs. 158.8 ± 12.6, $p < .0001$).

Although both groups demonstrated gains in flexibility from pre- to post- treatment assessments, the slight gain for the no-pain group was very small and not statistically significant ($p < .56$), while the gain in the pain group was judged clinically relevant and was statistically significant ($p < .0001$).

2. Muscle response time to sudden load

The time of the muscle response was measured in terms msec of delay between the onset of the sudden load as indicated by the load cell on the tray and the onset of the EMG response of the paraspinal muscles. The response time of increased EMG activity was accurately determined by use of the wavelet technique. Aural and visual sensory cues as to the moment of impact were masked with a white noise in headphones and a blindfold. Randomizing the movement when the weighted ball was released minimized learning effects. Therefore, the participant was unable to anticipate exactly when the weighted ball would strike the instrument tray.

Figures 5 and 6 indicate the difference of response time between the pain and no-pain group. These scores are the average scores of both sides of the low back in pre- and post-stabilization exercise. There is decreased response time, especially in the pain group, following back stabilization exercise. This indicated the response time is faster following stabilization exercises in the pain group ($p<0.05$).

At the first ball drop, there was no difference of response time on the dominant and non-dominant side back before and after stabilization exercises. This indicated that the subjects were unable to understand the exact characteristics of ball without anticipatory activation.

In Table 1, the dominant side of the response time in the pain group was 99.22 msec and the no-pain group was 91.92 msec at the first ball drop. The response time of the pain group delayed compared to no-pain group. This indicated the sudden ball drop might relate the delays of trunk stabilization especially, in the pain group.

Table 2, following stabilization exercise, the response time in the pain group was 90.00 msec and the normal group was 86.28 msec at the first ball drop. At the second ball drop before the spinal stabilization exercises, the response time for the pain group was 68.55 msec and 75.64 in the normal group. However, there were no statistical differences between these groups. These results indicated that there were delays of response time at the first ball drop, especially in the pain group.

Following the stabilization exercise, the response time is faster in the pain group (59.00) than in the normal group (89.42), especially with the second ball drop ($p<0.05$). This indicates that a spinal stabilization exercise intervention changes the neural mechanism by which the erector spinae muscle responds. Therefore, the patients with chronic LBD are able to respond faster following stabilization exercise with improved neuro muscular function.

Tables 3 and 4 indicate the non-dominant side of the response time in the pain group was 95.55 msec and the normal group was 87.92 msec at the first ball drop. Following stabilization exercise, the response time in the pain group was 79.88 msec and the normal group was 83.78 msec at the first ball drop. At the second ball drop before the spinal stabilization exercises, the response time for the pain group was 87.11 msec and 73.64 in the normal group. These results indicated that there were slightly faster response time at the second ball drop. However, there were no statistical differences between these groups ($p>0.05$).

Discussion

There is a growing scientific basis supporting active rehabilitation programs as an effective means of achieving lasting relief of pain and disability in the chronic low back pain population (Waddell, 1995). The clinical role that exercise and, more specifically, the neuromuscular system play in the treatment of subjects with a back pain and especially chronic LBD.

This study investigated the effect of stabilization exercises only in the chronic LBD group. Although subjects in the experimental group attended the exercise program, subjects in the normal group were not given the same amount of contact time. A sham exercise group could have been included in the design of this study to investigate specific outcomes of exercises in the future.

Effect of spinal flexibility

The spinal flexibility improvement indicated that the pain group exhibited increased spinal flexibility following spinal stabilization exercises on both the right and left side of the back. The spinal flexibility was increased from 131.0 to 144.1 in the pain group ($p<0.05$). The no-pain group was increased from 157.6 to 158.8 ($p>0.05$). The no-pain group was not significantly changed ($p>0.05$).

The spinal flexibility test was performed as one means of quantifying a patient's combined axial motion, as it would be used in functional context. This indicated that there is more decreased spinal flexibility in the pain group than in the normal group before the exercise program. However, this was increased following spinal stabilization exercises.

Effect of response time

The lack of clinical research in the neuromuscular system appears largely due to the difficulty in accurately diagnosing conditions of chronic LBD, with little regard for the neuromuscular system. There is also growing support in the literature affirming the important role the neuromuscular system plays in providing segmental control and stability to the lumbar spine (Aspden, 1992).

The dominant side of the response time in the pain group was 99.22 msec and the no-pain group was 91.92 msec at the first ball drop. The delayed response in the pain group related that injuries occur as a result of sudden movement because the neuromuscular system overreacts, and in the process, soft tissues containing nociceptors and propriocepters are damaged (Lavender, 1993). Also, the response time of erector spinae activity after sudden trunk loading has been shown to be longer in patients with low back pain than in healthy control subjects (Wilder, 1996).

Previous soft tissue injuries may have irreversibly damaged proprioceptors, and therefore an adequate fast reflex response to a sudden loading may not have been possible. The delay in response time must be compensated for by an altered recruitment pattern (Radebold, 2000). The patients with chronic LOD, In particular, based on clinical observation, physical therapists anticipated delayed activation of spinal muscle in subjects with symptoms of shoulder impingement. The results of this study provided support for this premise.

It is evident that there is a need for further research into the involvement of the neuromuscular system in specific diagnostic groups. The results from this study support use of stabilization exercise intervention to alter the neural control mechanisms by which the erector spinae muscle respond. It is important to understand the potential role of the neuromuscular system in a patient with chronic LBD.

Lumbar stabilization exercises is the form of training begins with the spine in a neutral position defined as the lumbar spine posture of the least pain, biomechanical stress and potential risk for injury. The patient is taught to maintain this position while surrounding muscles isometrically brace the spine. Improving muscle response times may serve to prevent further injuries to a painful lumbar spine. Extremity movements then can be performed in positions from supine to standing, with or without the addition of weights or resistance. The treatment goal is to maintain the neutral spine position with the least amount of pain while advancing to increasing complex daily or work-related tasks.

On the other hand, erector spinae muscle responses tended to be higher in the pain compared to the normal group before stabilization exercises and was significantly lower in pain compared to the normal group. From pre- to post-treatment, the no-pain group showed a trend toward increased muscle response ($p<0.05$), and the pain group showed a significant decrease in muscle response ($p<0.05$).

The results indicated that the spinal stabilization exercises depict a motor learning approach to treatment. It is evident that the mechanical stability of the lumbar spine is greatly dependent on the neuromuscular system to meet the stability demands. The neuromuscular system provides this dynamic stability through complex coordinated control between the local and global muscle systems.

As reviewed previously, there is research to implicate that changes do occur in the neuromuscular system in the presence of low back pain and chronic LBD, although most of this research has not been related to any specific pathology. There is also growing support in the literature affirming the important role the neuromuscular system plays in providing segmental control and stability to the lumbar spine (Aspden, 1992).

Conclusion

This study indicated that the spinal stabilization exercises improve the back flexibility and spinal response time. These effects related to the importance of the neuromuscular system, especially in the pathogenesis of chronic LBD. The spinal stabilization exercise serves to increase the stability of spine and flexibility with functional tasks, more specific preventive and rehabilitative strategies should be considered for patients with chronic LBD associated with mechanical stability. Active physical rehabilitation of patients with the spinal stabilization exercises in the chronic LBD patients has been shown not only to restore function, but it is also strongly associated with a faster response time. The faster muscle response time during unexpected events suggests that improved low back functions restore stability to the spine and could therefore help to protect it from further injuries. New technology with evidence-based practices is necessary to provide a means to evaluate effects of specific therapeutic exercises for patients with chronic LBD.

Abenhaim L, Rossignol M, Valat JP, Nordin M, Avouac B, Boltman F, Charlot J, Dreiser RL, Legrand E, Rozenberg S, Vautravers P. The role of activity in the therapeutic management of back pain : Report of the international Paris Task Force on Back Pain. Spine 2000 ; 25 : 4 : 1S-33S.

Aspden R. Review of the functional anatomy of the spinal ligaments and the lumbar erector spinae muscles. Clinical Anatomy 1992 ; 5 : 372-389.

Borkan JM, Cherkin DC. An agenda for primary care research on low back pain. Spine 21 : 24 : 2880-2884

Gilmore KL, Meyers JE. Using surface electromyography in physiotherapy research. Australian Journal of Physiotherapy 1983 ; 29 : 3-9.

Jette AM. Outcomes research : shifting the dominant research paradigm in physical therapy. Phys Ther. 1995 ; 75 : 965-970.

Kelsey JL, Githens PB, White AAIII et al. An epidemiologic study of lifting and twisting on the job and risk for acute prolapsed lumbar intervertebral disc. J Orthop Res 1984 ; 2 : 61-6.

Lavander SA, Mirka GA, Schoenmarklin Sommerich CM, Sudhakar LR, Marras WS. The effects of preview and task symmetry on trunk muscle response to sudden loading. Human

Factors 1989 ; 31 : 101-15.

MaKenzie, RA. The lumbar spine : Mechanical diagnosis and therapy. Spinal Publications pp. 89

Oxland TR, panjabi MM. The onset and progression of spinal injury : A demonstration of neural zone sensitivity. J Biomech 1992 ; 25 : 1165-72.

O'Sullivan PB, Phyly GD, Twomey LT, Allison GT. Evaluation of specific stabilizing exercise in the treatment of chronic low back pain with radiologic diagnosis of spondylolysis or spondylolisthesis. Spine 1997 ; 22 : 2959-2967.

Panjabi, M. The stabilizing system of the spine. Part 2. Neutral zone and instability hypothesis. Journal of Spinal Disorders, 1992 ; 5 : 390-397.

Radebold A, Cholewicki J, Panjabi MM, Patel TC. Muscle response pattern to sudden loading in healthy individuals and in patients with chronic low back pain. Spine 25 ; 8 : 947-954.

Richardson CA, Jull GA. Muscle control-pain control. What exercises would you prescribe? Manual Therapy, 1995 ; 1 : 2-10.

Saal J, Saal J. Nonoperative treatment of herniated lumbar intervertebral disc with radiculopathy : an outcome study. Spine 1989 ; 14 : 431-437.

Schenkman M, Hughes MA, Bowden MG, Studenski SA (1995). A clinical tool for measuring functional axial rotation. Phys Ther 75(2), 151-156.

Sung, P, Bottomley,JM, Echternach JL. Post hip fracture rehabilitation in subacute care. J Rehabil Outcome Meas, 3(2), 1-48, 1999

Teasell R, Harth M. Functional restoration - returning patients with chronic low back pain to work - revolution or fad? Spine 1996 ; 21 : 844-847.

Waddell, G. Modern management of spinal disorders. Journal of Manipulative and Physiological Therapeutics 1995 ; 18 : 590-596.

Wilder DG, Aleksiev AR, Magnusson ML, Pope MH, Spratt KF, Goel VK. Muscular response to sudden load. Spine 1996 ; 21 : 2628-2639.

Wilder DG, Pope MH, Frymoyer JW. The biomechanics of lumbar disc herniation and the effect of overload and instability. Journal of Spinal Disorders 1988 ; 1 : 16-32.

Zipp P. Recommendations for the standardization of lead positions in surface electromyography. Eur J Appl Physiol 1982 ; 50 : 41-54.

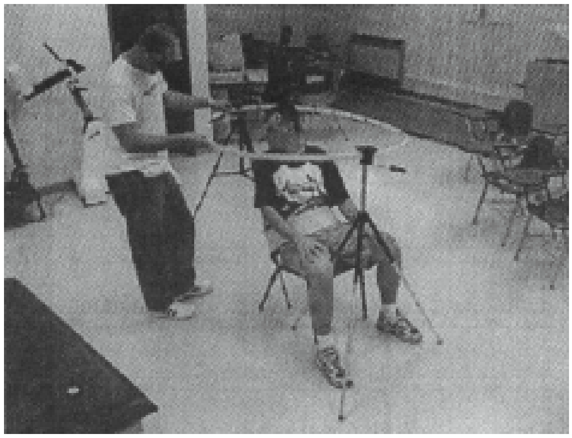

Figure 1. Spinal Flexibility Test. The device consists of a hoop, suspended by two tripods so that it can be adjusted relative to each subject' s height. The seated subject turns as far to the posterior as possible without lifting the buttocks from the chair seat. The degree of motion is determined using a pointer affixed to the head.

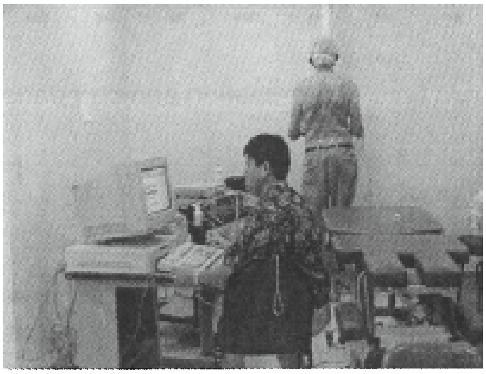

Figure 2. The set-up for the sudden applied load as used in this study. A weighted tennis ball was dropped onto a platform equipped with a load cell which could indicate the instant the ball hit the platform.

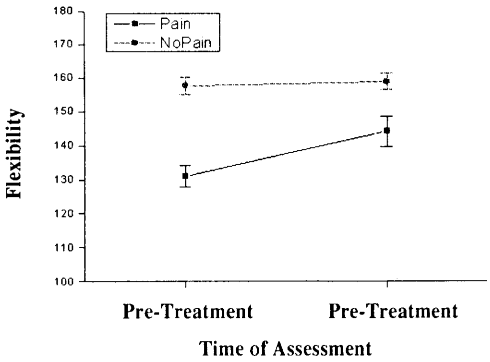

Figure 4. The interaction for spinal flexibility between treatment and time

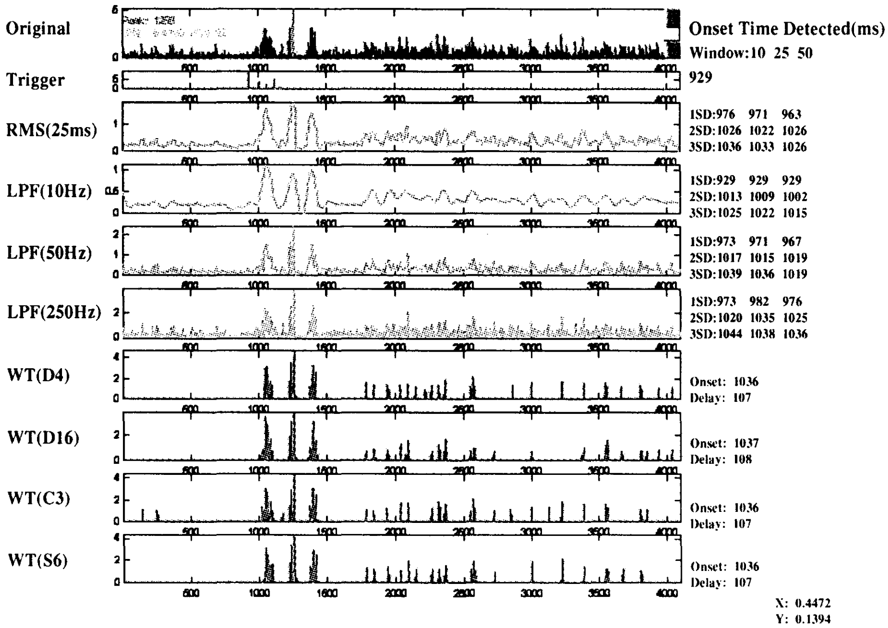

Figure 3. Automatic response time determination and comparison of various techniques

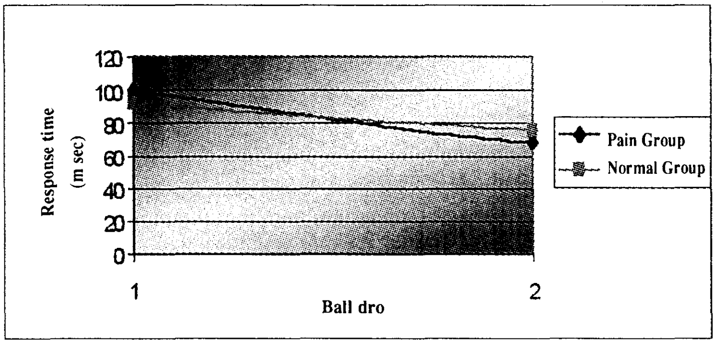

Figure 5. The difference of response time between grou before stabilization exercises

Table 1) The difference of response time on dominant side back before stabilization exercises

	Pain Group	Normal Group	T	P
1 ball drop	99.22 (38.09)	91.92 (37.67)	0.451	0.6565
2 ball drop	68.55 (16.62)	75.64 (39.04)	0.600	0.5557

Mean (Std Dev)
* (p<0.05)

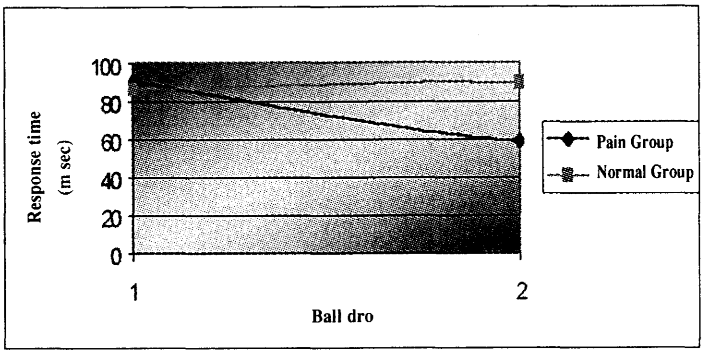

Figure 6. The difference of response time between grou following stabilization exercises

Table 2) The difference of response time on dominant side back after stabilization exercises

	Pain Group	Normal Group	T	P
1 ball drop	90.00 (45.89)	86.28 (41.87)	0.200	0.8433
2 ball drop	59.00 (9.15)	89.42 (47.26)	2.341	0.0345*

Mean (Std Dev)
* (p<0.05)

Table 3) The difference of response time on non-dominant side back before stabilization exercises

	Pain Group	Normal Group	T	P
1 ball drop	95.55 (41.59)	87.92 (38.53)	0.449	0.6578
2 ball drop	87.11 (37.86)	73.64 (27.21)	0.995	0.3313

Mean (Std Dev)
* (p<0.05)

Table 4) The difference of response time on non-dominant side back after stabilization exercises

	Pain Group	Normal Group	T	P
1 ball drop	79.88 (31.99)	83.78 (32.80)	0.281	0.7871
2 ball drop	66.44 (15.00)	82.85 (40.78)	1.369	0.1885

Mean (Std Dev)
* (p<0.05)