Balance Control Comparison between Subjects with and without Non-specific Low Back Pain*

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Abstract **Objective:** To compare the balance ability between normal people and non-specific low back pain (nsLBP) patients and explore the relationship between balance ability and muscle function in nsLBP patients. **Method:** Ten nsLBP patients as nsLBP group and 10 age and gender-matched healthy control subjects as control group were investigated. Posturography on balance platform and surface electromyography (sEMG) were performed to assess all the subjects' function of equilibrium and muscle activities of erector spinea(ES), multifidus(MF), abdominal external oblique (EO), hamstring (HS) and maximal gluteus (MG) bilaterally. **Result:** The nsLBP subjects had greater sway on anterior-posterior direction (Y-speed and Y-extension, P=0.05) on feet-together posture and bigger main axis (P=0.023) on nature standing with eyes closed when compared with controls. The iEMG ratios of right MG in nature standing (eyes closed)/ nature standing (eyes open) and feet-together (eyes open)/nature standing (eyes open) in control group were significant higher than that in nsLBP group (P=0.03 and P=0.013). **Conclusion:** Balance evaluation combined with sEMG measurement on trank and lower limb muscles provided some quantitative information about functional deficits such as postural control and muscle activities in nsLBP patients. This relationship should be emphasized in prevention and rehabilitation of nsLBP.

Key words balance; sEMG; low back pain

Low back pain (LBP) is one of the most frequent and disabling health problems affecting the society [1]. Clinically, one of the key questions is the link between the structural and functional changes and pain itself. It has been known that muscle function has close relationship with LBP, the recognition of structural and functional deficits in muscular function in regard to prevention and rehabilitation of musculoskeletal disorders is important[2—3]. Various functional activities of LBP patients are affected in different aspects. Balance is one of the important functions which has significant impact on human being's activities of daily living, such as standing, transfer and walking. Musculoskeletal disorders resulted from LBP may have an influence on balance performance[4—5], and pain stimulus itself may modify the normal signal input from muscles and sense organs, therefore pain may guide and modify balance performance[17]. The relationship between low back pain and postural control has been investigated by Byl and Sinnott [6]. This study showed that LBP patients had a greater degree of sway, a great use of hip strategy and a more posterior center of pressure in erect stance when compared with healthy controls. Force platform is a reliable instrument for balance measurement [7—8] at least when the test duration is greater than 10s. Surface electromyography(sEMG) is a commonly used technique to measure structural and functional characteristics of neuromuscular system,and differences in trunk muscle recruitment or neuromuscular control in back pain patients [9—12]. Currently about 80% of the back pain is non-specific origin, even the most careful clinical examination can not reveal pathological changes associated with LBP[13], which are classified therefore in most cases as non-specific low back pain (nsLBP). Our present study combined the sEMG measurements with balance evaluation in nsLBP patients, and expect to find the correlation between the postural sway and muscle activity of back and lower limb muscles in static standing position. The results of this study may give better understanding of the postural control and muscle function related to nsLBP, and therefore such information can be potentially utilized to render the treatment and therapeutic effects assessing more efficiently.

1 SUBJECTS AND METHODS

1.1 Subjects

Ten individuals with nsLBP and 10 healthy control subjects were involved and divided into two groups as nsLBP group and control group, respectively. The two groups were matched by age and gender. The nsLBP group was consisted of patients from the Department of Physical Medicine and Rehabilitation, First Hospital, Peking University in China. Normal working male and female aged 25—55 years old with recurrent episodes of nsLBP and body mass index <35 were the inclusion criteria. They

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complained at least two episodes over the last six months, pain was constrained to the back or radiated to the thigh, but all of them had the ability to do activities of daily living and were competent in their jobs they did. Among the 10 nsLBP patients, there was 4 used medication for alleviating pain, 6 palliated pain by physiotherapy, 3 had no treatment, 3 used both medication and physiotherapy for pain relief. However, all the patients only had mild pain at the time of testing. The subjects with red flag signs (signs of cancer, inflammation/infection, neural disease) and neuromuscular disease, specific LBP diagnosis (sciatica, disc herniation, fractures, spinal stenosis, post-traumatic paresis and muscle strains) and previous back surgery or cervical pain were excluded.

The control group was consisted of 4 healthy men and 6 women aged 25—55 years old and body mass index<35, reporting no LBP history, having no positive clinical signs during physical examination.

Clinical examinations were performed by the same physician for all the subjects in two groups.

The study protocol was approved by the Hospital Ethics Committee, First Hospital, Peking University and all subjects signed an informed consent prior to the participation. Descriptive information for the participants is outlined in Table 1.

Table 1 Clinical characteristics of the subjects ($\bar{x}\pm s$)

	nsLBP group	Control group	P value
Age (years)	40.2±7.5	40.4±7.9	0.95
Weight (kg)	65.5±7.4	67.8±11.6	0.60
Height (cm)	164.6±8.1	164.6±8.1	0.79
Upper leg length (cm)	41.8±3.3	39.3±3.7	0.12
Lower leg length (cm)	38.5±2.9	38.4±2.3	0.95
Exercises(h/week)	3.3±1.7	2.7±1.8	0.45
Lying time (h/d)	7.6±1.8	8.2±1.2	0.52
House working (h/d)	4.5±5.1	4.2±2.4	0.86
Distance of normal Standing(cm)	15.34±2.74	16.94±3.43	0.27

1.2 Testing procedures

Balance measurement was performed for each subject using Good balance system (Good balance, GB300, Metitur, Finland). The subjects were tested in a quiet room, and they were asked to stand in upright position on the balance platform with 4 testing items: nature standing with eyes open, nature standing with eyes closed, semi-tandem with eyes open and feet-together with eyes open. Each test item lasted for 30s, and repeated for twice with 30s intervals. The distance between foot in nature standing position for each subject maintained consistent from trial to trial. The results of the best performance for each subject were chosen as the balance measurement data for further analysis. Five parameters were calculated to evaluate the balance function; they were scaled X-extension, scaled X-speed, scaled Y-extension, scaled Y-speed and scaled velocity moment (Table 2). Scaled parameters were weighted by age, gender, height and weight.

Simultaneously sEMG signals (using MEGA6000 biomonitor Mega Electronics Ltd., Kuopio, Finland) of back and lower limb muscles were recorded when the subject was standing on the balance platform. The surface electrodes were applied on 5 muscles bilaterally, which were erector spinea (ES), multifidus (MF), maximal gluteus (MG), hamstring (HS) and abdominal external oblique (EO). Before electrodes application, skin was shaved, lightly abraded and cleaned with alcohol. Then the 2 electrodes with 75mm^{2}conductive area were placed on each testing muscle belly according to the recommendation of SENIAM [29] with 20mm each apart. Reference electrode was placed on the great trochanter of right femur. Raw sEMG signals were band-pass filtered (10Hz-200Hz) and full wave rectified. Root mean square (RMS), average EMG (aEMG) and integrated EMG (iEMG) were calculated for data analysis.

1.3 Statistics Analysis

SPSS 12.0 software was used to analyze all the data. Differences of clinical and physical characteristics and balance data were analyzed using paired sample t-test. Differences within groups were analyzed using independent sample t-test. The iEMG of different muscles in various position was normalized to the corresponding muscle iEMG in nature standing with eyes open. The comparison of sEMG data between two groups was calculated using Mann-Whitney U test. P value was set at less than 0.05.

Table 2 Balance comparison between nsLBP and control groups ($\bar{x}\pm s$)

	Control group	nsLBP group	P value
Item 1①			
Scaled-X-speed	2.45±0.76	2.51±0.87	0.87
Scaled-Y-speed	4.21±0.87	4.32±1.25	0.83
Scaled-X-extension	73.38±22.68	75.16±25.98	0.87
Scaled-Y-extension	126.33±26.22	129.49±37.57	0.83
Scaled-V-M	4.93±2.11	7.18±5.75	0.26
Item 2②			
Scaled-X-speed	2.90±0.82	3.05±0.71	0.68
Scaled-Y-speed	5.95±1.75	6.84±1.29	0.21
Scaled-X-extension	86.96±24.69	91.25±21.22	0.68
Scaled-Y-extension	178.32±52.30	205.21±38.30	0.21
Scaled-V-M	9.17±6.25	9.94±3.85	0.75
Item 3③			
Scaled-X-speed	7.33±2.61	7.66±1.95	0.60
Scaled-Y-speed	6.57±2.51	8.27±0.99	0.05*
Scaled-X-extension	219.62±78.29	229.80±58.6	0.60
Scaled-Y-extension	196.83±75.27	238.04±29.80	0.05
Scaled-V-M	21.16±9.41	25.98±9.36	0.17
Item 4④			
Scaled-X-speed	9.29±1.05	10.33±3.88	0.42
Scaled-Y-speed	8.39±1.15	8.03±2.09	0.63
Scaled-X-extension	185.53±20.90	206.36±77.46	0.42
Scaled-Y-extension	167.58±22.93	160.26±41.69	0.63
Scaled-V-M	29.23±9.07	33.70±21.94	0.56

Note:①normal standing with eyes open,②normal standing with eyes closed,③feet-together eyes open,④semi-tandem

2 RESULTS

As shown in Table 1, there were no significant difference in patients′ age, gender and other clinical characteristics, such as leg length, foot distance of nature standing, lying time and exercises time between two groups. Table 2 illustrated that the nsLBP patients presented a significantly greater Y-axis sway (Y-speed and Y-extension, P=0.05) on feet-together posture and bigger main axis (P=0.023) on nature standing with eyes closed during balance measuring when compared with controls. However, no significant difference in the balance parameters was found on other postures between two groups. But the iEMG ratio of nature standing (eyes closed)/nature standing (eyes open) and feet-together/nature standing (eyes open) of right MG in control group were higher than that in nsLBP group (P=0.03 and P=0.013) (Table 3).

Table 3 Comparison of iEMG ratio in 10 muscles between nsLBP and control groups ($\bar{x}\pm s$)

	Control Group	nsLBP group	P value
Right ES			
R1①	1.21±0.35	1.10±0.13	0.13
R2②	1.05±0.20	1.12±0.17	0.49
R3③	1.09±0.23	1.03±0.26	0.65
Right MF			
R1①	1.11±0.12	1.06±0.08	0.60
R2②	1.10±0.11	1.10±0.12	0.97
R3③	1.04±0.22	0.93±0.36	0.65
Right MG			
R1①	1.08±0.08	1.00±0.08	0.03*
R2②	1.28±0.44	1.04±0.08	0.013*
R3③	1.04±0.15	0.97±0.20	0.54
Right HS			
R1①	1.17±0.41	1.11±0.31	0.54
R2②	1.09±0.21	1.16±0.20	0.65
R3③	1.04±0.32	1.30±0.37	0.09
Left ES			
R1①	1.04±0.06	1.02±0.05	0.35
R2②	1.13±0.24	1.11±0.20	0.71
R3③	1.06±0.25	0.92±0.15	0.09
Left MF			
R1①	1.10±0.13	1.01±0.06	0.09
R2②	1.29±0.37	1.12±0.26	0.60
R3③	1.14±0.35	0.99±0.12	0.18
Left MG			
R1①	1.04±0.08	1.00±0.05	0.13
R2②	1.43±0.94	1.10±0.22	0.49
R3③	1.39±0.97	1.02±0.19	0.13
Left HS			
R1①	1.42±1.01	1.04±0.09	0.08
R2②	1.20±0.52	1.09±0.46	0.54
R3③	1.48±1.40	1.15±0.44	0.76
Right EO			
R1①	0.99±0.04	1.01±0.05	0.11
R2②	1.36±1.02	1.09±0.11	0.35
R3③	1.54±1.20	1.09±0.18	0.90
Left EO			
R1①	1.00±0.03	1.00±0.04	0.35
R2②	1.34±0.67	1.08±0.07	0.78
R3③	1.54±0.86	1.05±0.16	0.24

Note: ①R1=iEMG of normal standing with eyes closed/iEMG of normal standing with eyes open, ②R2=iEMG of feet together/iEMG of normal standing with eyes open, ③R3=iEMG of semi-tandem/iEMG of normal standing with eyes open

3 DISCUSSION

The majority of LBP studies have just focused on the trunk, specific assessment involved static and dynamic muscle strength, endurance, muscle activation pattern and the fatigability, magnitude of trunk muscle activation etc [14]. However, trunk is a part of whole body, performance of whole body should be taken into consideration to guide treatment and measure recovery progress. Balance assessment is usually emphasized on the ability of the subjects to maintain a static upright posture under various support and visual configuration. Researchers found [6] that LBP patients had greater postural sway when compared with healthy controls under certain conditions in upright standing. This study showed the nsLBP patients presented greater sway on anterior-posterior direction (Y-speed and Y-extension) when they stood feet-together with eyes open, but no difference was found on other postures. This result is not exactly consistent with previous report which showed increased sway on both medial-lateral direction and anterior-posterior direction [15]. Another investigator reported [16] that sway in medial-lateral direction was reliable enough to measure increased postural sway of chronic LBP patients during tasks which challenged visual input only but especially during tasks which involved increased complexity in addition to challenged visual input. The possible explanation of different results is probably due to the nsLBP patients in this study were of mild clinical symptoms which are more likely to present greater sway during complex tasks and in the circumstances of sensitive position; This they only showed much unstability on posture with less support area (feet-together). In addition, the test items adopted in this study were relative simple and the input interference was different from previous studies, and a wide range of balance response between individuals existed [16]. The mild symptoms and moderate reproducibility of the balance tests increase the variation and reduce the possibility to detect each difference between groups and test items.

Chronic pain patients frequently complain poor balance control [14], and it is well documented that patients suffering from LBP have diminished lumbar position sense [17—19], and poor postural control [20,11]. Clinically there is no identifiable reason responsible for nsLBP being found with physical examination, even with radiological protocol such as CT and MRI. However it seems most likely this situation involves injuries of spinal ligaments and capsular of zygapophyseal joint which have important sensory function in feedback control of joint position, and injuries of annulus fibrosus which are richly supplied with mechanoreceptors. All these will lead to a disturbance of the control of trunk balance. In addition, it´s supposed that a certain level of muscle strength and endurance is necessary for optimal postural control[1]. Muscular deficits from nsLBP including wasting of the extensor muscle mass [21], reduced trunk muscle force[22], reduced endurance of trunk extensor muscles [23] and longer trunk muscle reaction latencies[24—25] will limit the capacity to correct trunk perturbations. Proprioception is one of the three determinant factors influencing balance, and impaired proprioception in back pain patients [26,17] is another reason contributing to the decreased postural control.

It's proposed that the postural control system utilizes open-loop control mechanisms over short-term and closed-loop control mechanisms over long-term to maintain upright stance [30]. In the case of human postural control system, an open-loop control system may correspond to descending commands which set the steady-state activity levels of the postural muscles. Pain and fear of pain probably modify the postural control strategy adopted by the nsLBP patients who leads to the changes of the levels of muscle activity across the lower limb joints. The steady-state behavior of the open-loop postural control mechanism is more unstable in nsLBP subjects, the output of the overall system has a greater tendency to move away from a relative equilibrium point. On the other hand, there is research suggesting[27] that fear of pain may disrupt normal control of trunk muscles, which represents a change in the motor program at the cognitive level. In addition to the balance functions closely related to the central nervous system, postural control as above mentioned is determined by the biomechanics of musculoskeletal system, especially that of the trunk and lower limbs, such as feet support area, stability and structure of the joints, and muscle force. Musculoskelatal disorders is one of the most common problems affected functions in LBP patients, involves decreased motor skill, muscle force or coordination[1].

The sEMG signals of muscle activation for back extensors, hip extensors and abdominal muscles during the subjects maintaining balance under different conditions were gained in this study. Instead of normalized to model-view-controller (MVC), in this study compared the iEMG ratio in different postures divided to that in normal standing (eyes open) position between two groups were compared, trying to illustrate the muscle activity change during keeping balance. Right MG showed significant high ratio in normal standing with eyes closed and feet-together in control subjects. There may be two probable factors contributing to this result. Firstly, nsLBP patients' muscle activity was insufficient to keep balance in more difficult posture with eyes input interference and small support area which resulted in unstable swaying on anterior-posterior direction. Secondly, the viscoelastic tissue damage in the nsLBP subjects resulted in increased lumbar mobility and therefore decreased stability, they needed higher muscle activation to keep trunk balance in normal standing which led to relative low ratio. It indicated MG playing an important role in balance performance and it is susceptible to LBP and being compromised functionally. Previous study showed that MG is more fatigability in chronic LBP patients[28]. Only the muscle activation of right MG showing difference between the two groups is possibly associated with the fact that all the subjects are right-side dominated. In our study, there was no difference in other muscles between two groups. It is possible that this type of static test did not demand maximal effort from the subjects and they may had optical back muscle performance to manage this situation. Dynamic measurements which provide more detailed information on muscle coordination, synergies, strategies and the timing of muscle responses with EMG, as well as kinematic techniques, would be needed.

In conclusion, although the causes of LBP in most cases have not been found by present techniques, posturography of platform combined with sEMG measurement would reveal functional deficits such as balance and muscle function in nsLBP patients, even with mild symptoms and signs. So, in clinical intervention for nsLBP, functional activities and muscle motor skill training should be paid attention to. The cause-result relation of LBP-balance-muscle activation alteration is unclear but the interruption of any factor in the chain will facilitate the rehabilitation progress of LBP. The results of present study indicated that preventive and rehabilitation approaches should place emphasis on specifically coordinative exercises of gluteus muscles to eliminate the dysfunction.

However, our study is a pilot study with small quantity of samples, for further investigations with large number of subjects and other analytic methods should be carried out to confirm our findings.

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