

## The Effect of Fatigue and Instability on Postural Control Parameters in Standing Posture in Healthy Adults and Patients with Chronic Low Back Pain

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Article information	Abstract
<p>Article history: Received: 12 June 2011 Accepted: 25 Aug 2011 Available online: 29 Dec 2011</p> <p>Keywords: Migraine Helicobacter pylori Aura</p> <p>*Corresponding author at: Department of Physical Therapy, Faculty of Medicine, Tarbiat Modares University, Tehran, Iran. E-mail: beahrpeyf@modares.ac.ir</p>	<p><b>Background:</b> This study aims at analyzing the effect of fatigue and instability on postural control parameters in both healthy people and patients with the chronic nonspecific low-back pain.</p> <p><b>Materials and Methods:</b> In this non-experimental case-control study, oscillations of center of pressure were statistically analyzed in 16 healthy people and 15 patients with the chronic nonspecific low back pain. The analysis was conducted through two stages: before and after fatigue and under both stable and unstable surfaces.</p> <p><b>Results:</b> Under the pre-fatigue, stable condition, there was not any difference between the two groups. Both fatigue and unstable surface changed our variables (sway area, range, velocity, frequency and total power of the signal). All the changes in variables were significant in the low-back pain group; while changes in the healthy group only covered the time-domain variables. The effect of instability was higher than that of fatigue.</p> <p><b>Conclusion:</b> The postural control system for patients with low-back pain before fatigue and under stable condition, revealed sufficient competence to provide postural stability and its function cannot be differentiated from that in healthy people. Meanwhile, different mechanisms were used by these patients to confront stability challenging factors and further neural activity was required to counteract such factors.</p>

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### Introduction

Low-back pain is the main cause of inability to perform work particularly in the industrial societies [1] which its prevalence across various countries during lifetime of people has been reported 80% [2, 3]. Unfortunately, in spite of several medical protocols, clinicians have failed to find a satisfactory treatment for this disease; thus, it necessitates more precise study and analysis of the occurred changes in functions of various systems involved with the disease.

Today, many professional activities are independent from any severe force and high muscular strength, but their fundamental requirement is to generate and maintain lower levels of force during a long period of time or frequently. It shows the high importance of analysis of the muscular endurance for such patients and its better potential to be used rather than other factors including the muscular strength [4]. Fatigue is able to affect the imposed load on the spine and/or injury tolerance and to act as a kind of disturbance to the postural control process [5, 6]. Changes of neuromuscular control and coordination occurring as the result of neuromuscular fatigue can maximize damages of the lumbar region

[4, 7]. Changes of center of pressure (COP) and center of mass (COM) displacement and velocity are important instances of such alterations [8, 9].

In order to analyze these factors, we can examine different variables. Because of its functional relevance in keeping body stability and preventing damages, the postural control factor can be one of the most important ones. Stability in this regard refers to the dynamic stability or in other words, the ability of the postural control system to return to the initial dynamics after confronting with the disturbing factors. In this view, the condition in which body in the standing posture generates the lowest oscillations necessarily is not defined as the stable condition; because body's oscillatory motions (postural sways) are interpreted as exploratory motions seeking the best solution to cope with the unexpected disturbances. Thus, instability can be considered as an effective factor to bring about low-back pain or at least as an associate abnormality; such consideration lets us attain a better understanding of the postural control system behavior and changes caused by chronic low-back pain (CLBP).

Numerous studies indicate that the elective behavioral difference in postural control system can just be revealed under stability challenging conditions. As a result, in order to get a good understanding of the postural control system behavior in patients with CLBP, the patients are put in a stability challenging condition and then the control system responses are dealt with. It is necessary to note that, no study has directly dealt with the effect of instability and fatigue on the postural control system behavior in people with CLBP yet. Therefore, this study tries to compare the effect of fatigue and instability on postural control system of healthy people and patients with CLBP.

## Materials and Methods

As a non-experimental case-control one, this study was conducted in winter 2011 in the ergonomics laboratory of University of Social Welfare and Rehabilitation Sciences. Sixteen healthy volunteers and 15 patients with chronic nonspecific low-back pain were included in this study (table 1). Members of the case (patients) group were selected based on the following criteria: range of age: 20-40 years old; history of pain and discomfort in the lumbar area without pain refer to the leg and feeling low-back pain continuously or recurrently for more than three months in a way that no anatomic or pathologic evidence for justifying their back pain has been found [10]. Exclusion criteria were symptoms for nerve root irritation, vertebral or leg fracture and/or surgery history, any type of neurologic disease, any observable deformity in spine and or legs and rheumatoid diseases. Members of the control (healthy) group were selected so that their age, gender, BMI and level of physical activity were matched to those of the case group.

The members of our sample were informed with details of the study and signed the consent form. They were tested in two stable and unstable supporting surface conditions which were provided by standing on the force platform and a tilt board, respectively. In order to remove the learning confounding factor, all volunteers exercised standing on the tilt board for two minutes before beginning the main stages of the test. Before test, subjects got acquainted with the Borg scale, which was used to determine fatigue level.

The placement order of subjects on the force platform in the two conditions (with or without tilt board, before and after fatigue), was being set randomly before conducting the tests by lot. Then the barefoot subject stood with or without a tilt board, three times for each, over the force platform and he/she was asked to stand motionless while looking at a circle placed at his or her eye level at 2 meters distance. For the position of feet, the sole criterion was that the heels should be stood in a parallel line; the patient was allowed to set distance between his/her feet and the angle of them freely which would be recorded and fixed in all other trials. Ten seconds after standing over the force platform, the output data were recorded for thirty seconds.

In this stage, between any two tests, the patients were allowed to rest for two minutes in order to make sure that he/she is not fatigued before the next test. After this stage, the subject stood over the force platform without tilt board and lifted two equal and symmetrical halters equivalent to 15 percent of his body weight by his hands up to his waistline and again returned them to the floor, and then while his hands did not separate from halters, he repeated the lifting and lowering task.

This practice was continued up to the point at which a scale over 17, in Borg rating scale, was reported by the subjects. This scale in this study has been considered as the scale showing fatigue and also was a point at which lifting and lowering got wrapped up. Scale 17 in the Borg rating scale is equal to the very difficult condition. Observing ethical considerations and making sure about preventing any damage to the subjects, particularly patients with CLBP were the reasons for why we set this scale as the highest possible rate in this study. After finishing the "lifting and lowering" stage, the subject immediately was positioned on the force platform in standing posture with and without tilt board and the output data of the force platform was recorded for thirty seconds for each posture. In order to keep the subject fatigued, no rest time was predicted for this stage.

In this study, acquisition and recording COP signal were conducted by a force platform (Kistler, Switzerland, 9286 AB). COP data were sampled with 100<sub>Hz</sub> frequency digitized by an A/D board and analyzed offline. Our variables in this study were COP displacement range, sway area, mean frequency and total signal power in both AP and ML directions. Kolmogorov-Smirnov test was used to check variables normal distribution. The effect of independent variables, i.e. support surface stability and fatigue, were appraised using repeated measures MANOVA and the effect of CLBP on the dependent variables was measured using independent *t*-test of SPSS-16 software.

## Results

Comparison of the anthropometric variables showed no significant difference between the two groups (Table 1).

**Table 1.** Comparison of the anthropometric variables in the two groups

Group	Control	CLBP	<i>p</i> -Value
Age(years)	23.15±2.04	25.33±3.45	0.082
Height(cm)	165.54±9.85	163.17±6.42	0.110
Weight(kg)	61.77±9.70	64.17±14.23	0.317
BMI	22.42±2.44	24.15±3.02	0.096

**1. Fatigue effect:** The results showed that in non-LBP subjects, fatigue under the stable condition, significantly increases COP velocity across both planes and sway range in the AP direction (*p*=0.04). However, in patients with CLBP and under the stable condition, the effect was significant on sway area, range, velocity, mean frequency and total signal power in sagittal plane and sway range and velocity in the ML direction (*p*=0.02).

Under the unstable surface condition, fatigue resulted in decrease of sway range and increase of its velocity and area in non-LBP subjects, while in patients with CLBP, not only COP moved faster, but also the mean frequency and total signal power increased significantly ( $p=0.03$ ). In this condition and in non-LBP subjects, fatigue resulted in

sway range decrease in ML direction while for patients and under the unstable surface condition, fatigue did not bring about any significant difference in the studied variables ( $p=0.12, 0.09, 0.08$  for sway range, velocity and area, respectively) (Table 2).

**Table 2.** Comparison of the dependent variables across various levels of the independent variables

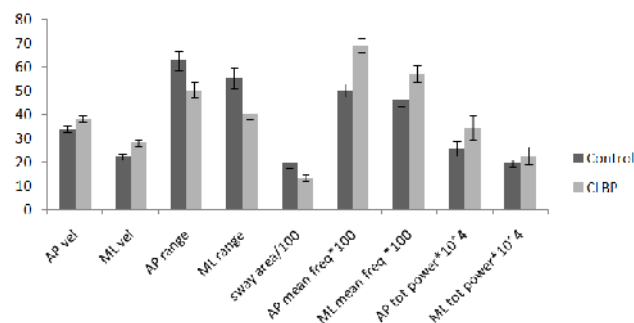
Condition	Group	Plane	Range	Velocity	Frequency	Total Signal Power	Sway Area
Pre-Fatigue/Stable	Control	AP	15.57±2.85	7.07±0.96	0.26±0.06	3.26±2.06	109.82±56.89
		ML	8.81±1.76	7.54±0.95	0.13±0.10	1.52±0.74	
	CLBP	AP	16.05±3.27	7.08±1.21	0.25±0.08	4.60±2.00	113.95±96.72
		ML	10.95±2.56	7.49±1.30	0.14±0.14	1.44±0.59	
Pre-Fatigue/Unstable	Control	AP	61.63±9.12	26.99±5.09	0.36±0.17	5.89±3.07	1765.31±682.32
		ML	55.39±16.20	21.32±3.23	0.17±0.12	2.52±1.74	
	CLBP	AP	51.57±9.25	33.35±5.85	0.53±0.21	9.81±5.28	1246.71±398.22
		ML	45.37±8.62	26.24±3.20	0.30±0.13	4.73±2.71	
Post-Fatigue/Stable	Control	AP	21.95±12.59	8.56±1.84	0.31±0.15	5.02±3.21	215.27±215.14
		ML	12.38±4.62	7.98±1.09	0.15±0.10	2.73±0.85	
	CLBP	AP	31.48±8.02	10.44±1.00	0.38±0.07	9.56±3.77	216.10±92.82
		ML	16.40±7.31	8.19±1.20	0.18±0.16	3.46±0.74	
Post-Fatigue/Unstable	Control	AP	69.67±16.49	33.71±5.93	0.42±0.21	7.38±4.77	1682.68±1006.04
		ML	55.06±16.51	21.94±4.21	0.19±0.12	3.31±2.01	
	CLBP	AP	54.28±13.20	38.02±5.04	0.58±0.13	3.31±2.16	1331.52±489.97
		ML	45.03±8.36	27.97±5.23	0.36±0.14	7.35±2.51	

**2. Effect of instability:** In both groups and in the pre-fatigue condition, unstable surface resulted in increase of sway velocity and range, across the anterior- posterior direction, and the sway area ( $p=0.02$ ). In CLBP group, not only the abovementioned variables, but also frequencies of motions of COP and total signal power were increased as well ( $p=0.04$ ). In the non-LBP group, response of all variables to instability of the surface in the frontal plane was similar to that of the sagittal plane; meanwhile patients' response in the frontal plane was not different from that in the control group. In the post-fatigue condition and in the control group, the unstable surface caused significant increase of sway area and sway range and velocity across the sagittal plane ( $p=0.03, 0.01, 0.04$ , respectively). In this group, a similar effect was observed for all of the mentioned variables in the ML direction.

The effect of the unstable surface under the condition subsequent to fatigue in patients with CLBP included significant increase of all variables in both planes ( $p=0.00, 0.04, 0.01, 0.04$  and  $0.03$  for sway range, velocity, area, mean frequency and total power of the signal, respectively) (Table 2).

**3. Effect of group:** The results showed that there was no significant difference in the above-mentioned variables across AP and ML directions between healthy people and patients with low-back pain in the pre-fatigue condition while standing on a stable support surface; however, under the same condition and in response to support surface instability, in the sagittal plane, mean frequency, total power of signal and sway velocity of COP in patients were higher than those in the control group ( $p=0.01, 0.03, 0.02$ ), while sway range in the sagittal plane and sway area of COP got greater values in control subjects ( $p=0.03, 0.02$ , respectively). In frontal plane, sway velocity in patients was the only variable to be significantly higher than that of the control one ( $p=0.02$ ).

In the stable condition and after fatigue, sway velocity, mean frequency and total signal power across the sagittal plane in patients group was more than those in the control one, while in the ML direction, only sway velocity showed statistically significant difference ( $p=0.03$ ) (Table 2). In unstable condition and after fatigue, across both AP and ML directions, sway velocity, mean frequency and total signal power were more in patients group, while CLBP subjects had smaller magnitudes of sway range and area ( $p=0.01, 0.03, 0.01, 0.02$  and  $0.03$ , respectively) (Fig.1 and Table 2).



**Figure 1.** Comparison of the dependent variables in the post-fatigue/unstable condition. The differences among variables are all statistically significant.

## Discussion

For non-LBP subjects, imposing fatigue under the stable condition increased both sway range and velocity of COP across the sagittal plane, while the only significant change in the frontal plane was the COP velocity increase. For patients with CLBP, under the stable condition and following fatigue, sway range, area and velocity were increased.

Fatigue in these patients also increased range and velocity of COP motion across the frontal plane. It seems that the healthy and patients' responses to fatigue under the stable condition were somehow identical and in both groups, disturbance caused by fatigue brings about further oscillations and larger sway magnitude of the COP. Fatigue acts as a kind of disturbance to the postural control system and affects both sensory, afferent and actuator components [11]. This will lead to decrease of precision and accuracy of function of the postural control system and subsequently increased demand of the system to more neural activity which is manifested as increased COP velocity. With regard to a fixed 30-sec period for all tests increased velocity of COP means increased sway path length as well. The increased sway range of COP is a kind of seeking and anticipatory behavior in order to deal with the possible challenges caused by the above mentioned condition [12]. Such findings are consistent with the previous studies on increased sway path, range and velocity of COP against the imposed disturbances [4, 8, 13-15]. Salavati et al. have also pointed to the disturbance of the stability mechanisms in the form of increased stability indices confronting fatigue [16].

Under unstable condition, fatigue increased sway velocity in both control subjects and patients with CLBP in the sagittal plane. One of the outstanding differences between responses of the two groups to fatigue under the unstable condition was decreased oscillation range in both sagittal and frontal planes in the control group, while CLBP patients made no significant change in their sway amplitude in either planes. Under the stable condition, the oscillation range for the non-LBP subjects increased while the postural control system's response to fatigue under the unstable condition was decreasing the oscillation range in both planes. This behavior which reflects the role of stability condition on the response of the postural control system to fatigue can be justified as the anticipatory function of the control system. It seems that although increased movements of COP might act as a seeking behavior of the postural control system compensating consequences of fatigue as a disturbing factor, regarding the fact that unstable support surface considerably increases the oscillation range, hence, the excessive increasing of the range under this condition cannot be considered as a practical strategy and may even exclude the subject from the limit of stability. In CLBP patients, neither such decreased oscillation range (as in control subjects) nor increase of sway range (as under the stable condition) was seen facing fatigue under the unstable condition. This finding also approved the hypothesis that some postural strategy differences of the patients with CLBP with non-LBP subjects will be masked under normal conditions and confirms that more complicated and difficult postural tasks are needed to reveal such changes.

Under both stable and unstable support surface conditions, CLBP patients' response to fatigue included increased frequency of COP motion, while for the control group, fatigue brought about no significant change in the frequency domain variables in either condition. This

shows another aspect of the different elective strategies utilized by the control system in CLBP patients and non-LBP subjects in responding to the postural disturbances (fatigue here). Seemingly, given the neuromusculoskeletal deficits in CLBP patients and increased stability requirements of these patients, the postural control system needs further activity to cope with the challenges caused by instability which becomes evident in the form of increased frequency of COP motions and total signal power [17]. Davidson et al. either, did not find any changes in variables of frequency domain in healthy people and only reported increased COP sway velocity and area after fatigue [8].

The last point to be mentioned about effect of fatigue is that none of the studied variables were changed in frontal plane in patients with CLBP under the unstable condition. Our interpretation of this finding is that instability of the support surface causes so large changes in the studied variables that they come to kind of saturated point, hence adding another challenge, e.g. fatigue, will not add to this compensatory alterations of the postural control system's response.

As the results show, for the patient group, all the studied variables in the sagittal plane increased significantly while for the non-LBP group, only time-domain variables were increased and no significant changes were observed in the frequency-domain ones. This finding might demonstrate that instability of the support surface in comparison with fatigue imposes more stability challenge to the postural control system and brings about further reactions. However, considering instability and fatigue levels applied is necessary while interpreting this finding. Both patient and non-patient subjects give identical responses in the frontal plane to instability before becoming fatigued which included increase of COP velocity and range. The only difference in the frontal plane was seen in their response to instability of the supporting surface in the post-fatigue condition, where besides the changes observed in the pre-fatigue condition, both mean frequency and total signal power were increased in patients with CLBP, but no such changes were observed in the frequency-domain variables of non-LBP subjects. It is also confirmative that parts of the alterations of the postural control system in CLBP are just visible in stability challenging conditions.

Another discussable finding of the current study is the lack of any significant difference in the studied variables of the two groups under the pre-fatigue/ stable condition. In confirmation of the previous studies, it can indicate the sufficiency of the postural control system under the ordinary condition and before confronting stability challenging factors [10].

Under the same condition of stable support surface and in response to fatigue, the patients' response covered not only the COP velocity but also the mean frequency and total power of the signal; while the latter changes were not observed in the control group. It seems that given the increased stability requirements of patients with low-back pain, increasing COP movement's frequency in line with COP velocity is the elective and seemingly specific

strategy of the CLBP patients to cope with postural disturbances. Popa believes that the response of the postural control system depends primarily on the internal estimations of disturbance rather than direct sensory signals [18]. Regarding the evidence showing the persistent changes in the nociceptive and proprioceptive processing centers of the CNS in the presence of chronic and long-term pain, broader ranges of the applied variables to cope with instability, might be attributable to the differences among internal models of body dynamics of the CLBP patients.

Under the easiest condition (pre-fatigue/stable), the studied groups did not show any significant difference in terms of sway range and area. After introducing fatigue, patients with CLBP showed further sway range and area than the control subjects. It is noticeable that as the result of an unstable surface, sway range was decreased in the patient group. Although, subsequent to standing on the unstable surface, the movement velocity of COP and thus the distance it traversed were increased in the CLBP group, these larger movements took place in a smaller area. Apparently, the postural control system acts very specifically against different disturbances, so that the nature of the postural disturbance plays a vital role in setting the selected strategy by the system. Under the most difficult condition (post-fatigue/ unstable), COP velocity, mean frequency and total signal power were again greater in the patient group than the control one; however, non-LBP subjects enjoyed greater sway range and area. These findings are consistent with the rigidity theory applied in the postural control system behavior of patients with CLBP and suggest that such rigidity will become evident in more complicated and difficult postural tasks [22]. Conclusively, our findings show that,

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comparing with controls; patients with CLBP utilize different strategies confronting stability challenging factors. On the other hand, the stability requirements of such patients are more than those in healthy individuals and they need further neuromuscular efforts to maintain stability. Another finding indicates that the postural control system's response is based on the nature of the disturbance.

One of the most important limitations of the current study was lack of availability of kinematic data in case of which we would gain a better understanding of the strategies of the CNS in response to stability challenging factors.

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### Authors' Contributions

All the three authors were engaged in the design of the study. The first author was also responsible of data collection and analysis. The first and the third author were engaged in discussing the findings and writing the final manuscript.

### Conflict of Interest

No conflict.

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