The Effect of Frontal Loading on Static and Dynamic Balance Reactions in Patients with Chronic Low Back Dysfunction

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Abstract

The purpose of this study was to compare the balance reactions of chronic low back dysfunction (CLBD) patients with control subjects. Thirty one patients (13 women and 18 men) and 29 healthy individuals (14 women and 15 men) were tested using a computerized balance system. Eight balancing situations, in the standing position, were examined: with and without visual feedback, platform stable or moving angularly, with and without supporting a weight held by the hands (the frontal load). Balance was expressed in terms of body sway. Findings have indicated that CLBD patients manifested significantly larger postural sway than control subjects in 2 out of the 4 unloaded tests and in all loaded tests. Absence of visual feedback as well as sinusoidal perturbations of the platform resulted in significant increases of sway in both groups. However the magnitude of these increases were group dependent. It is concluded that CLBD patients present balance impairment which may be aggravated by external loading.

Key words: balance, back pain.

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In recent years the measurement of balancing performance has attracted considerable attention both in theoretical research and clinical circles. This attention has been generated by and in turn was instrumental in the development of various balance measurement systems, some of which are commercially available.

Studies based on these systems have indicated that the maintenance of balance, under static or dynamic conditions, is a complex function involving major sensory and motor contributions [16]. Among the former, the visual, vestibular and proprioceptive systems provide the neural input necesary to continuously adjust and correct body position in relationship to the supporting surface and the surrounding environment [13, 19, 25]. Positioning of the body is achieved by means of the muscular system which by way of displacing or arresting the motion of various body segments, enhances and maintains balance or prevents its loss [7].

The main clinical interest is clearly oriented towards the elucidation of balance disorders in the elderly and the neurologically involved patients. However, balance may be compromised in other patient groups predominantly those presenting with orthopedic dysfunction, such as ankle [24] or knee [4] instability. Impaired proprioceptive and increased latency in muscle contraction were implicated as contributing factors [8]. Another clinical group whose balance performance may be compromised comprises of patients presenting chronic low back dysfunction (CLBD). These patients are known to be afflicted with various symptoms affecting the musculoskeletal apparatus such as pain, limitations in the range of motion and a reduction in muscular strength and endurance [14, 17]. These may detrimentally affect balance performance. However, the number of studies dedicated to the relationship between CLBD and balance performance is very limited.

In a study which compared CLBD patients with normal subjects, the sway (dispersion) and location of the center of pressure (COP) were measured during performance of various demanding situations, with and without sensory feedback, which included single-legged and intermittent heel and toes stance [3]. The findings indicated that sway was generally higher in the experimental group, particularly with respect to the most stable (stable platform, eyes open) and most unstable condition (single-legged, eyes closed). As expected sharp increase in the measured parameters was noted in the absence of sensory input. It was also apparent that patients tended to shift their COP even more posteriorly and were using the so-called hip strategy more often. In another study which focused on lateral flexion characteristics in CLBD patients relative to control subjects a similar tendency of maintaining the COP in a more posterior position was apparent [9]. A follow-up study of CLBD patients during rehabilitation has indicated that training over a period of 6 weeks significantly enhanced balance performance, particularly in patients over 45 years of age [10].

Since the integral segment comprising the head, arms and trunk (HAT) constitutes about two thirds of the bodyweight, controlling its motion is critically important for the maintenance of total body balance. This function is largely performed by the extensors and flexors of the trunk, both of which, but the former in particular, are known to be impaired in CLBD patients [1, 11, 14, 17, 22, 23]. It would therefore seem that these patients may find it increasingly difficult to maintain balance while manipulating or holding objects. Therefore, the purpose of the present study was to compare quantitatively balance performance in CLBD patients and normal subjects during isometric exertions in the frontal plane.

Method

Subjects

28 women and 32 men, aged 20-60 took part in the study. The CLBD group consisted of 31 patients, 13 women and 18 men. The control group consisted of 29 subjects, 14 women and 15 men without any history of LBD. The average age of the CLBD and control group was 41.6 and 31.1 respectively.

Patients were diagnosed as having disc protrusion or herniation (N = 17), degenerative changes (N = 8) or idiopatic LBD (N = 6). All complained of pain which was located at the low back and some experienced radiating pain but not below the level of the mid-thigh. Symptoms persisted for at least 6 months but at the time of testing none of the patients was in acute pain. All patients answered a questionnaire aimed at excluding those presenting with neuromuscular, systemic or vestibular pathologies, cervical injury, ankle instability or taking medications with which could have potential CNS effects.

Instrument

The Balance Testing System (Chattanooga Instruments, 101 Memorial Dr., Chattanooga, TN 37405, USA) was used to measure the balance performance. This apparatus consists of a platform which measures 60 x 70 cm. Two force plates compatible with the size of a shoe, are placed freely on the platform. They contain 4 load cells, 2 each, one under the ball of the foot and one under the heel with a force sensitivity of 2.4 mv/lb. The maximal allowable load for a single force plate is 375 lb. The platform itself may remain stationary but it can also move linearly (forward / backward) or about an axis situated at the center of the platform at a constant frequency of 8.33 cycles/min. The normal forces sensed by the plates are displayed in real time. A dedicated software enables the derivation of several parameters such as the sway and location of center of pressure.

Testing protocol

Each examination consisted of 2 sets of 4 individual tests of static and dynamic balance. During the first set the subject stood with arms hanging freely and feet spaced out at a comfortable distance of 12-14 cm. During the second set he was asked to hold, with forearms flexed 90 deg, a plastic box measuring 25 x 20 x 10 cm which contained weights related to his bodyweight (bw) according to the following paradigm: for a bw up to 50 kg: 3 kg, 51-65: 4 kg, 66-80: 5 kg, 81-95: 6 kg. This weight range was based on a pilot study in which a group of patients were asked to rate their perceived exertion and comfort in supporting weights using this particular position. Table 1 describes the 8 testing conditions. Notably, in tests 1, 3, 5, 7 subjects (eyes open) were asked to concentrate on a target in the form of a white solid circle, 3 cm in diameter, located at a distance of 2 m away. Tests 2, 4, 6, 8 were performed with the eyes closed. The most taxing condition was the eighth test in which subjects were asked to maintain balance while holding the weight with their eyes closed and subject to sinusoidal perturbation in the form of ± 4 deg of dorsi-plantarflexion. All individual tests lasted 25 s with a 2 min inter-test interval. Each individual test was repeated twice with the second score being the representative. A full testing session lasted approximately 45 min.

Load adjustment

Using weights of different magnitudes, repeated tests have shown that the heaviest and lightest subjects in the CLBD group could support 6 kg and 3 kg respectively for a duration of 25 s without succombing to fatigue and under various test conditions. These weights were therefore set as the upper and lower limits with intermediate weights corresponding to bw subdivisions.

Data analysis

The parameters measured were the center of balance (COB) along the mediolateral: x-axis and the antero-posterior: y-axis and the sway index (SI). The COB is defined as the coordinate of the average of the sampled (at 100 Hz) x and y points comprising the balance trajectory. The SI,

Table 1. Test situations - abbreviations.

Test number	Test parameter	Abbreviation
1	eyes open, platform stable	OS
2	eyes closed, platform stable	CS
3	eyes open, platform moving	OM
4	eyes closed, platform moving	CM
5	OS + load	WOS
6	CS + load	WCS
7	OM + load	WOM
8	CM + load	WCM

in cm, is defined as the standard deviation of the sampled points around the COB. The statistical analysis involved application of t, sign and Wilcoxon tests as appropriate, calculation of correlations and ANOVA with repeated measures. The level of significance was set at $p < 0.05$.

Results

In terms of the COB(x) and COB(y), no significant differences were noted between the groups in any of the 8 testing conditions. On the other hand, the sway index differed significantly between CLBD patients and normal subjects in all test conditions except two of the unloaded conditions: OS and OM. These findings are depicted in Fig. 1. Figure 2 shows variations in COB(y) namely the tendency to shift the body forward or backward as a function of the test situation. Table 2 outlines significant interactions indicated with respect to the SI. For instance, as apparent from the first line in the table, with the platform stable, the status of vision: eyes open or closed was associated with a significantly different effect on CLBD patients compared with control subjects. Likewise, various test situations comprising the eyes, open and/or closed, with or without load interacted significantly with the platform status - stable or moving, to result in a significantly different performance profiles among patients compared with normals.

Discussion

This preliminary study compares balance performance in CLBD patients versus control subjects. Its novel element consists of incorporating an external flexor moment in the form of a weight which acts as a constant isometric bias. As pointed out, trunk extension muscle function in CLBD patients is significantly impaired, compromising also their other important role, that of controlling the positioning of the trunk. It was postulated that besides introducing a functional aspect to balance testing, frontal loading of the trunk would directly tax these muscles and therefore accentuate differences between patients and subjects. Before discussing the results, consideration of the method used to impose this load is essential.

In principle, a load corresponding to the individual ca-

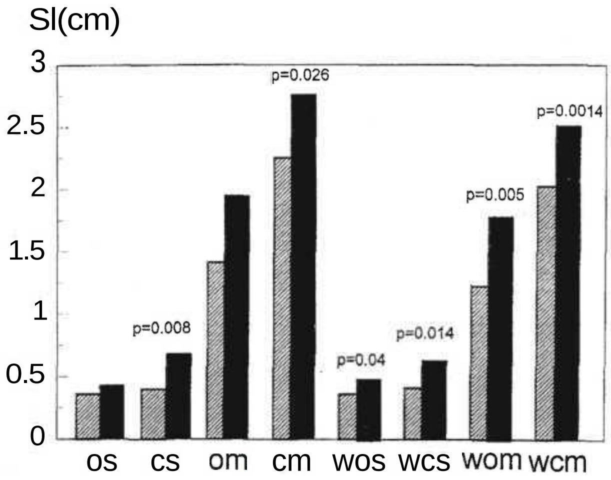
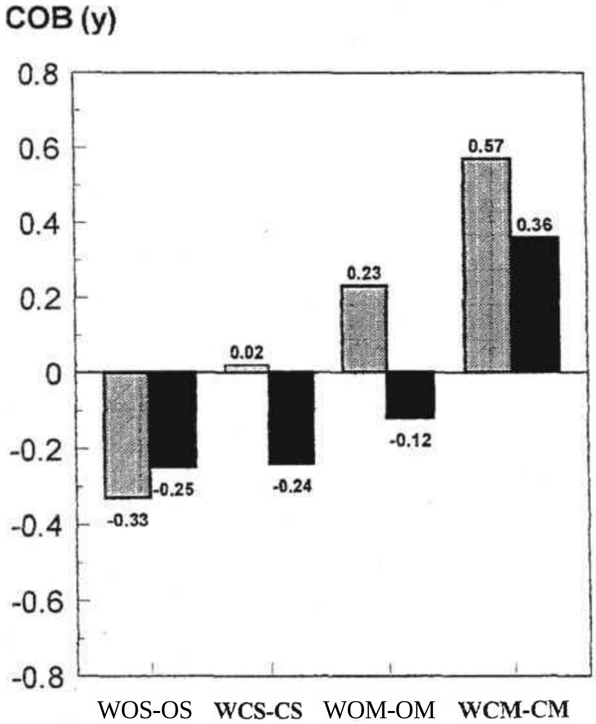


Figure 1. Sway index values: normal subjects (lightly dashed bars) vs. CLBD patients (solidly dashed bars).



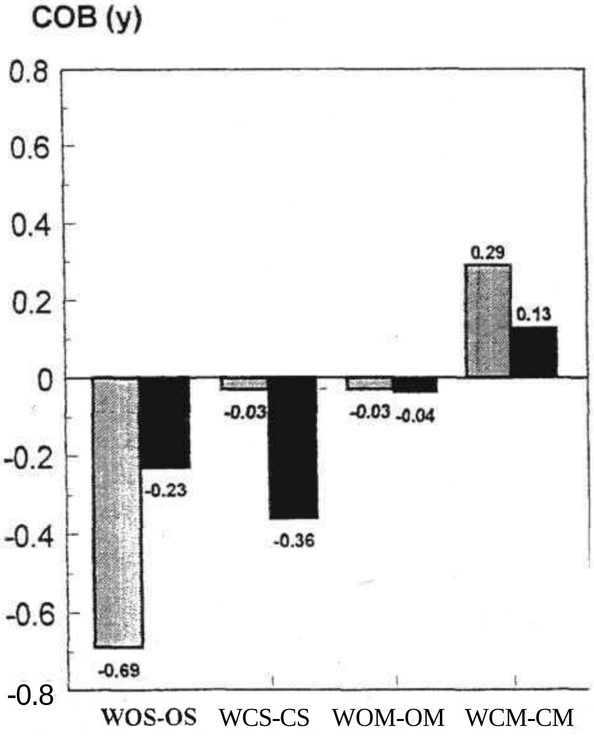


Figure 2. Shifts in COB(y). Left: normal subjects in loaded (dashed bars) vs. unloaded tests. Right: CLBD patients (same markings).

Table 2. Significant interactions in SI between groups.

Interaction	Test Situation	Mean diff CLBD	Mean diff Normals	p value
Eyes (O/C)	Platform (S)	0.24	0.03	0.01
Platform (S/M)	Eyes (O)	1.51	1.094	0.005
Platform (S/M)	Eyes (O) + load	1.30	0.86	0.002
Platform (S/M)	Eyes (C) + load	1.88	1.60	0.04

pacity of the extensor muscles would have been a more optimal choice. Since the duration of the balance test is 25 s, endurance rather than strength had to be assessed in order to comply with the physiological requirements. However, maximal isometric contractions performed during such a period of time cannot possibly be sustained without fatiguing the patient and/or exposing him to risk. The proposed solution was therefore to test isometric strength and adjust the isometric load employed in the balance test as a percent of this strength (eg 30%).

In a pilot study which was undertaken prior to the present study, an attempt was made to measure the isometric trunk extensors strength of CLBD patients using a positioning and stabilization unit together with an instrumented load cell. However the isometric strength measurements proved not to be well-tolerated by the patients beside revealing large test-to-test variations and had therefore to be abandoned in favor of a fixed load. Findings relating to normal subjects quoted isometric extension strength in absolute as well as in relative (force in lb/bw) units, indicating some correlation between strength and weight [5]. A second pilot study was hence undertaken to establish the magnitude of weights which could be safely supported by the hands, for a period of 25 s. Though not without its drawbacks, we believe that this method of adjusting the resistance is sufficiently straightforward to be adopted in the clinic where simplicity of procedures as well as the ability to grade the effort and conduct follow-up assessments is of prime importance. However, it should be emphasized that the current method may have detrimentally affected the acuity of the findings and hence a more systemtic way of prescribing the load is desired.

The use of two rather than one force platform is noteworthy. The Balance Testing System records 4 normal forces, acting on the heel and the ball of the feet in order to calculate the position of the center of pressure, COB(x, y) and the sway index. The use of two fully instrumented 6 degree of freedom force platform has been reported [12, 15]. Of a major significance to the present study was the finding that the mediolateral (ML) forces decayed in what could be described as an exponential fashion relative to the opening between the feet. Specifically, with a spacing of up to 15 cm the average ML force was a negligible 1% of bodyweight [15]. Since the present test situation prescribed a comfortable spacing of 12-14 cm, the test findings result in no appreciable loss of generality. From the practical viewpoint it should also be borne in mind that a set-up involving two instrumented force platforms of the sort used in these studies is very expensive besides requiring highly trained personnel capable of utilizing and interpreting the voluminous amount of information derived from a single test. In the present study we have attempted to use a much simpler configuration which admittedly can provide a significantly more restricted view of the interactions operating in balance maintenance. On the other hand the system is commercially available and provides users with that sort of data which may be sufficient to some extent and clinically interpretable in common terms.

In the unloaded test series, significant differenecs between the groups were indicated where visual feedback was not available (CS, CM). In terms of the patient group, these conditions were particularly demanding. It has been indicated that impairment of trunk muscles involved in addition to strength loss, diminished proprioceptive performance [20, 21] resulting in some functional instability and increased postural sway. It has also been shown that visual feedback could reduce postural sway by 30-60% [6]. Therefore where proprioception is not fully preserved, such as may occur in CLBD, the role of the visual apparatus could be even more critical. On the other hand, in the frontal loading series, significant inter-group differences were noted in all tests with a concomitant increase in the sway although the tendency to shift the center of balance forward was equally conspicuous.

Examination of the differential effect of the platform status, stable or moving, on the study parameters revealed that only sway was affected. CLBD group manifested a significantly larger change in sway during 'loaded' balancing with eyes closed or open and 'unloaded' balancing with eyes open. When the base of support is unstable, the demand from all sensory-motor systems is increased as a function of the complexity of the movement. As far as the trunk extensor muscles are concerned, a secondary neural trauma that may prolong the latency of response cannot be ruled out [20, 26]. Thus the mechanical compensation could be compromised due to both strength deficiency and speed of response. On the other hand, it should be emphasized that this specific evaluation tool does not allow for random perturbations and thus the existence of motor learning components is feasible. In other words, inter-individual discrepancies may also reflect the rate at which the motor skills are acquired. To assess the contribution of mastering the balance task would have entailed a piecewise analysis of the record, eg every 3-5 s, an option which unfortunately does not exist in the present software.

The findings have also indicated that upon comparison of the most stable with the least stable balancing tests within each series (unloaded, loaded) the experimental group manifested significantly higher differences in the sway than the control group. These findings may be relevant in 'crisis' situations where a sufficiently large shift in body segments positions may necessitate the incorporation of different (additional) strategies such as the 'hip' or 'step'. Each in turn would require more profound involvement of the skeleto-muscular apparatus which in this particular case may not be available.

Examination of the variations in COB(y) reveals that although the CLBD vs. normal findings did not reach statistical significance, there was a clear linear trend of shifting the bodyweight forward as a function of the task complexity. This relationship which was partly expressed as a significant interaction between the sway index and the platform-loading combination is a further support for the use of an external moment in balance testing. It would seem from the results that compared with normal subjects, CLBD patients have a 'posterior bias'in terms of COB(y). In other words, while supporting an external flexor moment, they had a pronounced tendency to locate their center of balance in a more posterior position. This was evident in all loaded test situations. A possible explanation to this phenomenon is the above mentioned extensors strength deficiency. By reclining backward, the external moment could be balanced with a smaller active contribution from these muscles. The fact that this reaction pattern was not evident in the unloaded situations may point out to some adaptive process but these issues require further research.

From the therapeutic standpoint the findings of this study underscore former attempts to recondition pelvic girdle and trunk muscles in CLBD patients using unstable supports during gait [2]. Findings derived from this study have indicated that following treatment, better recruitment patterns were achieved which persisted when patients resumed walking on a normal plane. It is possible that in similarity to other muscle groups [14], trunk extensors could be reconditioned with the result that CLBD patients could achieve better postural control and hence expose themselves to a lesser level of risk.

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