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Effects of deep breathing on dynamic balance in patients with chronic mechanical low back pain

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ABSTRACT

The diaphragm serves a dual role as the primary muscle of respiration and a core muscle that contributes to postural control. It is important to optimize both roles. However, in cases of low back pain (LBP), this optimization is compromised due to alterations in respiratory patterns in patients with chronic mechanical low back pain (CMLBP). The literature has not confirmed whether a deep breathing pattern (DBP) might enhance the diaphragm's postural control function in patients with CMLBP. Primarily, this study investigated whether DBP might improve dynamic balance in patients with CMLBP. Secondarily, it examined differences in dynamic balance between patients and healthy subjects using DBP versus their spontaneous breathing pattern (SBP), as well as the correlation between pain and dynamic balance in the patient group across both breathing patterns. Dynamic balance was assessed in 15 patients with CMLBP and 15 matched healthy subjects during DBP and SBP. Patients with CMLBP significantly improved their dynamic balance when using DBP. However, healthy subjects showed enhanced dynamic balance using either breathing pattern. Furthermore, pain did not significantly correlate with dynamic balance control in the CMLBP group. It is recommended to encourage DBP in patients with CMLBP, as it may enhance dynamic balance, probably by emphasizing the diaphragm's postural role.

KEYWORDS

Low back pain; balance; deep breathing; diaphragm; posture

1. INTRODUCTION

Low back pain (LBP) is pain localized below the costal margins and above the inferior gluteal folds. Muscle spasm and lower back stiffness may develop, and symptoms may or may not include developing leg pain. Chronic back pain refers to conditions that lasts for a period that exceeds 12 weeks (Koes, Van Tulder, & Thomas, 2006; Vlaeyen et al., 2018)

Core stabilization has developed to be a main component in managing low back pain (LBP). The diaphragm is a core muscle that functions in both respiration and postural control. The diaphragm helps to maintain intra- abdominal pressure, and hence augment core stability, through its attachment to the lumbar spine (Stephens et al., 2017). However, when it comes to the management of LBP the postural role of diaphragm seems to receive less attention compared to other core muscles specially transversus abdominus and multifidus (Sannasi et al., 2023). The dual task of diaphragm as a main muscle of respiration and as a core stabilizer as well, put a high demand on the diaphragm in LBP patients to enhance lumbar stabilization, which might have a role in developing a disturbed breathing pattern. Disturbed breathing patterns seen in patients with LBP when involved in motor control tasks might be due to altered postural function of the diaphragm and transversus abdominus (Ostwal & Wani, 2014).

The other way around, Hodges, Eriksson, Shirley, and Gandevia (2005) suggested that respiratory movements represent a main challenge to posture control in patients with LBP. Since LBP is associated with abnormal patterns of respiration during motor control tasks (Ostwal & Wani, 2014), emphasizing a deep breathing pattern of respiration might help to restore normal breathing pattern during the balance control task in patients with LBP. Restoring normal breathing pattern might enhance the restoration of synchronized dual respiratory and postural functions of the diaphragm in patients with LBP.

Accordingly, the primary aim of this research was to identify the role of DBP of respiration in balance as a motor control task, in patients with LBP. This study has been controlled by matched healthy subjects. Secondary aims were to confirm whether balance control varies between patients with CMLBP and healthy matched controls, whether using SBP or DBP. Further, to find out whether pain intensity was significantly correlated with balance changes in patients with CMLBP using either pattern of respiration, SBP or DBP.

2. METHODS

2.1. Design and participants

This cross-sectional, case-control study was conducted in a laboratory setting in the faculty of Physical therapy, Cairo University.

Thirty subjects participated in 2 groups, 15 patients with chronic LBP (LBP group) and 15 healthy control subjects matched for age and gender (Control group). Participants' ages ranged between 20 to 40 years, and body mass index (BMI) less than 30 kg/m^2. Sample size has been calculated using Gpower software 3.0.10 based on a previous report assessing balance using Biodex balance system in LBP patients and matched controls (Karimi, Ebrahimi, Kahrizi, & Torkaman, 2008).

2.2. Instruments and procedures

All participants were assessed during their spontaneous breathing SBP and DBP for dynamic balance on Biodex balance system (BBS) (Biodex Medical Systems, Inc., Shirley, NY, USA). Further, participants in LBP group reported pain intensity before dynamic balance assessment as well as immediately after each dynamic balance assessment. Patients were recruited if they were complaining of LBP localized to the lower back for at least 3 months. Patients were excluded if they had previous surgeries, disorders, injuries or fractures of the back, abdomen, or the lower extremities, visceral complaints that might refer pain to the lower back, radiculopathy or myelopathy. Further exclusion was for patients with visual, vestibular, neurological, metabolic or other disorders that might affect dynamic balance. Besides, none of the participants suffered from any cardiopulmonary diseases. The controls were volunteers who had no concurrent or previous complaints of LBP, and fulfil the other inclusion and exclusion criteria set for the patients with LBP (Figure 1).

Participants were interviewed to confirm their eligibility to participate in the study. Afterwards, eligible participants had a description of the study objectives and procedures. Those who agreed to take part in the study signed informed consent forms to confirm their participation. The study has acquired ethical approval from the faculty ethical committee at the number (P.T.REC/012/005061), and registered at clinicaltrial.gov registry (NCT06398249). Data collection extended between February 2024 and February 2025.

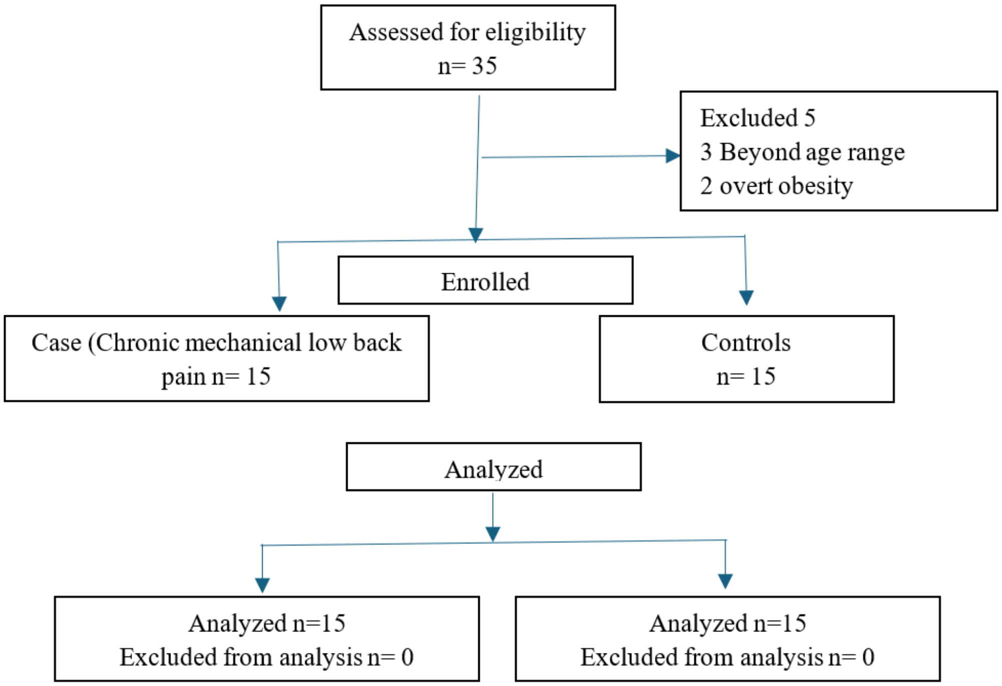


Figure 1. Study flowchart

Each participant had an appointment set at the balance laboratory at the Faculty of Physical Therapy, Cairo University. All appointments had been scheduled at the same time of the day to make sure that all participants had the same circumstances during measurements. The laboratory settings ensure adequate calm environment with adequate illumination to assist participants to focus on the assessment procedures. On arrival, the participants were introduced to the Biodex balance system (BBS). They started completing the data collection sheet including their demographic information. Participants' weight and height were measured and used to calculate their body mass indices (BMI). Then, they started a familiarization session on BBS, where they stood on BBS at the same stability levels that were used later for testing, levels 8 to 4 (easier to harder), for 20 seconds for each familiarization trial, and they used visual feedback from the Biodex display screen. They repeated familiarization trials 5 times using their spontaneous breathing pattern (SBP), and 5 times with deep breathing pattern (DBP). Deep breathing pattern involved deep inspiration and expiration, 5 seconds each, for 2 cycles. A period of one-minute rest was allowed for rest between these trials. Following the familiarization session patients took a rest of 10 minutes then started the measurement session. Using identical setup and measuring parameters as the familiarization session, each participant applied two measurement trials, one trial while participants used SBP and the other while they used DBP with one minute separation between measurement trials. The sequence of measurements for the two breathing patterns was randomized for each participant using a simple draw of cards labelled by breathing patterns from an opaque envelop. The outcome measures for measurement trials on BBS were the stability indices that the software of BBS calculates as a variance of its platform deviation. The system provides an overall stability index (OASI), anteroposterior stability index (APSI), and mediolateral stability index (MLSI). For patients in the LBP group, visual analogue scale (VAS) has been used to record pain intensity at baseline directly prior to testing, then patients reported immediately following dynamic balance assessment for each pattern of breathing. The intensity of pain they felt during assessment was recorded to find out whether pain intensities differed significantly between baseline (before measurements), and/or either of the two breathing patterns during dynamic balance assessment. Furthermore, pain intensities in both breathing patterns were correlated with the stability indices reported with the corresponding patterns.

2.3. Statistical analyses

Data analysis was carried out using SPSS (version 23, IBM Inc.). Demographic data were compared between LBP and control groups using independent t-test. Between and within groups comparisons were held using mixed model ANOVA with post- hoc pairwise comparisons of the results for each stability index: using groups as between subjects, and breathing pattern as within subjects' factors. Pearson correlation coefficient was used to correlate pain intensities during SBP and DBP trials and balance indices in the LBP group.

3. RESULTS

Data has been evaluated for normality using Shapiro- Wilk. Data sets were normally distributed, including both demographic and outcome parameters (Table 1).

Demographic data of the participants in both groups are presented in (Table 1). LBP and control groups included equal number of males (8) and females (7). Age, height, weight, and body mass index (BMI) were compared, and no significant differences were reported (P>0.05).

Table 1. Comparison between demographic data in patients in the LBP group versus healthy subjects in control group

Groups	**LBP**	**Control**	**Statistics**	
Demographic Data	**Mean (± SD)**	**Mean (± SD)**	**t- value**	**Sig.**
Age (years)	26.33 (± 4.21)	25.27 (± 4.54)	0.667	0.510
Weight (kg)	76.93 (± 9.17)	74.67 (± 4.27)	0868	0.393
Height (cm)	164.01 (± 8.53)	163.33 (± 5.86)	0.249	0.805
BMI (kg/m²)	28.51 (± 1.16)	28.01 (± 1.49)	1.006	0.323

The DBP showed significant enhancement of dynamic balance control in LBP group compared to SBP. However, this was not the case in control group where both breathing patterns showed comparable dynamic balance control. Results of this study showed that patients with CMLBP have less dynamic balance control compared to matched healthy subjects. Further, there was no significant difference between pain intensities reported at baseline or during either of the breathing patterns during dynamic balance assessment in LBP group. Although correlations exist between pain intensities and stability indices in LBP group, these correlations were non-significant.

Results showed that patients with CMLBP have better control over their dynamic balance during deep breathing than during spontaneous breathing. This was indicated by significantly lower OASI ($P< 0.001$), APSI (<0.001), and MLSI (<0.001) during DBP compared to SBP. However, in the control group the effect of DBP in dynamic balance was not significantly different from SBP for OASI ($P= 0.361$), APSI ($P=0.141$), or MLSI ($P=0.395$) (Table 2).

Table 2. Comparison between mean values of overall, anteroposterior and mediolateral stability indices with LBP and control groups.

Breathing Pattern		**Spontaneous Breathing**	**Deep Breathing**	**Statistics**	
Groups	**Stability Indices**	**Mean (± SD)**	**Mean (± SD)**	**f-value**	**Sig.**
LBP	OASI	8.51 (± 3.53)	6.38 (± 1.71)	21.530	0.000*
	APSI	6.80 (± 2.45)	5.24 (± 2.14)	42.771	0.000*
	MLSI	5.37 (± 2.78)	3.97 (± 1.73)	42.430	0.000*
Control	OASI	2.49 (± 0.64)	2.06 (± 0.29)	0.861	0.361
	APSI	2.08 (± 0.31)	1.72 (± 0.36)	2.297	0.141
	MLSI	1.43 (± 0.50)	1.25 (± 0.43)	0.747	0.395

**(significant at P<0.05)*

Comparing patients with CMLBP to controls, all stability indices, OASI, APSI, and MLSI, showed lower means in control subjects than patients with CMLBP during SBP ($P<0.001$), as well as DBP ($P<0.001$), which indicates better dynamic balance in control subjects (Figure 2).

Pain intensity recorded showed a non- significant difference between mean pain at baseline, during SBP, and DBP ($F_{(2,13)} = 1.372$, $P = 0.288$).

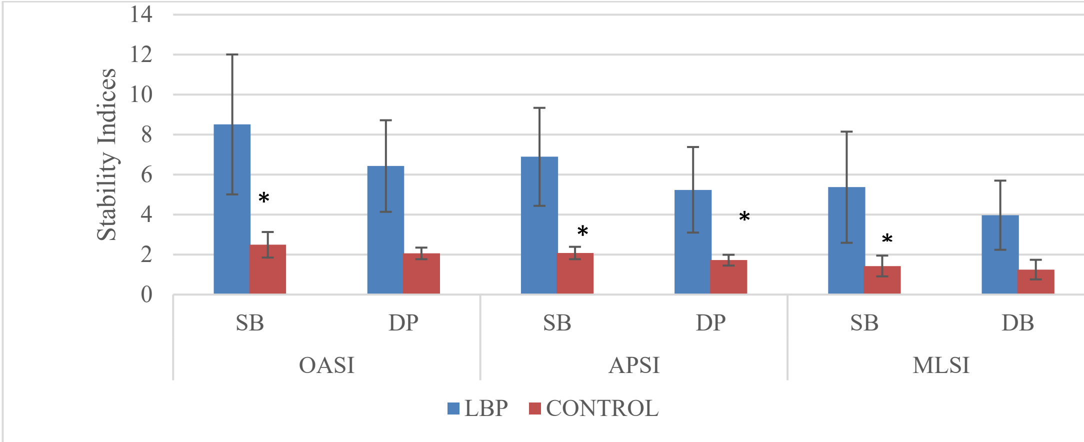
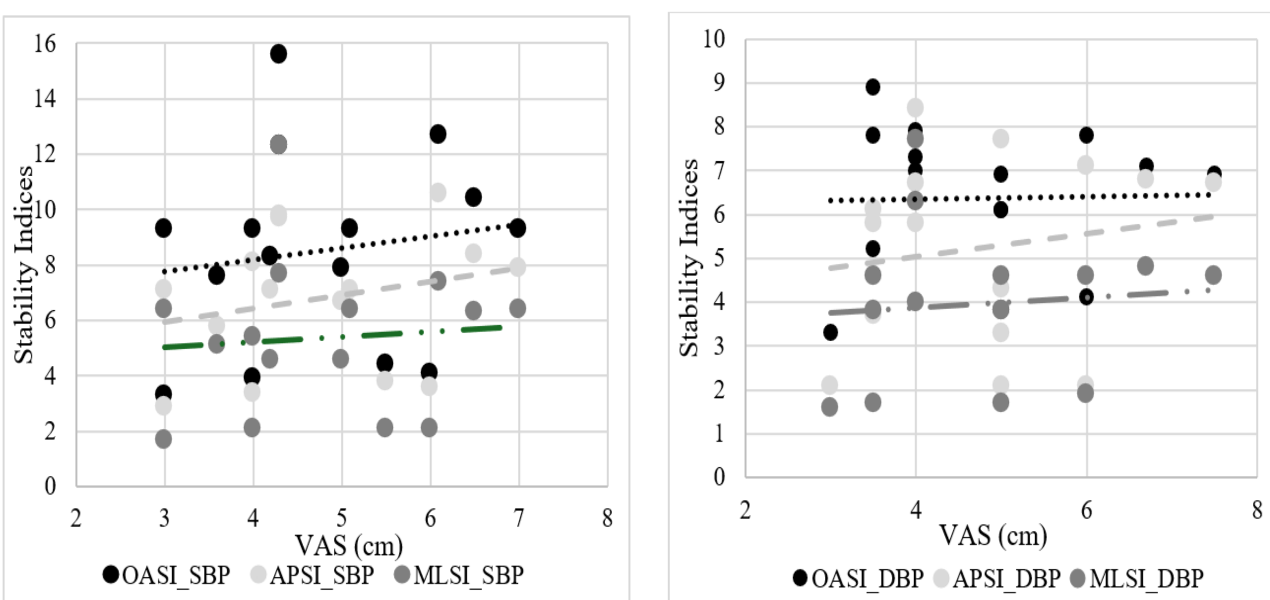


Figure 2. Comparison between patients with LBP and control subjects' stability indices (OASI, APSI, and MLSI) during using each of the spontaneous breathing (SB) and deep breathing (DB) patterns *(*Significant at P<0.05).*

Further, correlation studies were conducted between pain intensity and stability indices during SBP and DBP respectively in patients with LBP. Results showed non- significant positive correlations between pain intensity and OASI (r (13) = .151, P= 0.596), APSI (r (13) = .251, P= 0.380), and MLSI (r (13) = .081, P=0.773) during SBP. Likewise, non-significant positive correlations were reported between pain intensity and OASI (r (13) =.211, P= 0.944), APSI (r (13) =.161, P=0.567), and MLSI (r (13) = .091, P= 0.747) during DBP (Figure 3).



(A) (B)

Figure 3. Correlation between pain intensity and stability indices during A) SBP, and B) DBP.

4. DISCUSSION

Patients with CMLBP showed better dynamic balance control when using DBP compared to SBP. In support of the current study, promotion of a costal-diaphragmatic breathing pattern in healthy subjects was found to be associated with improvement in balance (Stephens et al., 2017). Suggestible, DBP may have increased the firing and proprioception input of the diaphragm and deep core musculature. This increase in muscles firing and proprioception may have contributed to the reported improvements in dynamic balance. However, it is worth mentioning that there are 3 differences when the current study is compared to Stephens et al., study; they studied healthy subjects only and they applied diaphragmatic breathing program for 8 weeks. Further, their study pointed out that emphasizing diaphragmatic breathing patterns to enhance static balance rather than dynamic balance assessed in the present study.

In another study Kocjan et al. (2018) used ultrasonographic assessment of diaphragmatic thickening and balance. They reinforced the idea that better diaphragm thickening during conscious deep breathing is related to better static balance. Although the current study did not measure diaphragm thickening during DBP, and it has been concerned with dynamic balance assessment, Kocjan et al., gave an indication that it is likely that this pattern reinforces diaphragm thickening during intended or conscious deep breathing, thus helps in improving balance. An additional explanation of the current results might be that patients with CMLBP appear to have both abnormal position and a steeper slope of the diaphragm this would affect their SBP involving diaphragm function (Kolář et al., 2012).

Therefore, it is suggestable that directing patients to emphasize DBP might drive towards a more normalized diaphragmatic function, pattern of breathing, and hence, improve dynamic balance in patients with CMLBP.

Other studies support the use of diaphragmatic breathing in rehabilitation of CMLBP. The studies mentioned that it is beneficial to add diaphragm training to the rehabilitation program for athletes with nonspecific CLBP (Otadi et al., 2021), and they reported that diaphragmatic training improved limits of stability in patients with chronic LBP as well (Finta, Boda, Nagy, & Bender, 2020; Otadi et al., 2021). Despite the differences in populations and balance assessment methods from current study, these studies provide additional support that these improvements in dynamic balance in patients with chronic low back pain might stem from emphasizing diaphragm respiratory as well as postural functions through DBP.

In controversy with current results Rodrigues, Gurgel, Gonçalves, Porto, and Soares (2018) reported that deep breathing increases the center of pressure (CoP) area, speed, and distance in elderly subjects. What may explain the difference in the findings between both studies is that the present study included a younger age group of patients with CMLBP. It has been reported that the elderly population has a lower balance capacity than younger subjects regardless of the existence of back pain. Moreover, differences controverting current results may be due to the difference of the measurements used for assessment (Vlaeyen et al., 2018). Rodrigues et al., 2018 measured CoP parameters during static posture. The current study assessed the effect of deep breathing during dynamic balance, with mechanical perturbations might have induced further spine and lower limb muscles activity. These factors, in addition to the activation of the diaphragm during DBP, might have enhance the control over balance during DBP compared to SBP.

Likewise, Hamaoui, Do, Poupard, and Bouisset (2002) disagreed with the findings of the current study as they reported that breathing at a slow breathing rate showed higher displacement of the CoP especially in anterior-posterior direction compared to quiet breathing in patients with LBP. These controverses with the current study where DBP was reported to show lower stability indices compared to SBP are likely due to the difference in outcomes measures and conditions of assessment. Where the current study examined dynamic balance control, they studied postural control during static standing.

Further, results of secondary outcomes in this current study showed that patients with CMLBP have worse (higher values) balance indices compared to matched healthy subjects. This was found irrelevant of their breathing patterns during testing, whether they used SBP or DBP. These findings support previous evidence that pointed out that patients with CMLBP have deficits in balance control (Zheng et al., 2024). Consequent to deficits in balance control in CMLBP patients are liable to decrease mobility (Smith et al., 2022), dysfunction (Sun, Li, Yao, Wu, & Yang, 2023), and higher risk of fall (Yalfani, Abedi, & Raeisi, 2022). In explanation of the compromised balance control ability in patients with LBP, researchers previously suggested that in healthy subjects' balance is controlled by multi-segmental, flexible and centrally organized (Brumagne, Cordo, & Verschueren, 2004; Mok, Brauer, & Hodges, 2004). On the contrary, this is not the case in patients with LBP who are reported to use a more rigid ankle-based strategy for balance control (Brumagne, Janssens, Knapen, Claeys, & Suuden-Johanson, 2008). The rigid balance control strategy is evident clearly during postural perturbations such as standing on unstable surface (Janssens, Brumagne, Polspoel, Troosters, & McConnell, 2010).

Moreover, regarding relating pain and breathing patterns to one another, Zheng et al. (2024) carried out a systematic review that reported no association between pain reduction and dynamic balance control indices in patients with chronic non- specific low back pain; a finding that supports the findings in the present work. Controversially, a previous research reported worse balance control in patients with CMLBP with high pain categorization (Mofateh, Bakhshi Feleh, Orakifar, & Behdarvandan, 2024). A conclusion that has not been detected in the current study. It is worth notice that authors in the Mofateh et al study have not reported such significant relation between pain intensity and balance when they studied patients with low pain categorization, which supported the findings in the present study. Accordingly, it sounds that the difference between the 2 studies is only seen in the group with high pain categorization in Mofateh et al., study, while the current study included patients with relatively lower pain intensities, and thus properly low pain categorization. That makes the results of the current study more correspondent to Mofateh et al., study in patients with low pain categorization.

A limitation of the current study is that the specific SBP used by patients with chronic mechanical low back pain (CMLBP) and healthy control subjects was not evaluated. Instead, the current study relied on previous findings demonstrating altered respiratory characteristics in patients with nonspecific low back pain (Mohan et al., 2018).

5. CONCLUSIONS

Emphasizing DBP has been found to be beneficial for improving dynamic balance control in patients with CMLBP. The improvement in dynamic balance control most likely stems from the enhancement of the diaphragm's postural control function as a core stabilizer. Therefore, patients with CMLBP are advised to implement DBP, even at a conscious level, until it gradually becomes automated.

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AUTHOR CONTRIBUTIONS

All authors contributed equally to the study's design, data collection, analysis, interpretation, and manuscript preparation. All authors reviewed and approved the final version of the manuscript.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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