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RESEARCH ARTICLE

Respiratory characteristics of individuals with non-specific low back pain: A cross-sectional study

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Abstract

Non-specific low back pain (NS-LBP) is known to cause respiratory dysfunction. In this study, we investigated alterations in breathing, respiratory strength and endurance, core stability, diaphragm mobility, and chest expansion among patients with NS-LBP and healthy individuals. The specific aim of the study was to correlate between respiratory function and other variables among NS-LBP patients. Thirty four patients with NS-LBP were matched with 34 healthy participants before undergoing total faulty breathing scale, spirometer, respiratory pressure meter, chest expansion, ultrasound, and pressure biofeedback measurements. There were signs of faulty breathing in the NS-LBP patients when compared to the healthy participants. Diaphragmatic mobility and respiratory muscle endurance were lower in the NS-LBP group. Chest expansion exhibited a significant decrease at the level of the fourth intercostal space in the NS-LBP group, but respiratory muscle strength and core stability were not significant between the two groups. Positive correlations were found to be fairly significant regarding respiratory muscle strength. The findings of this study indicated altered respiratory characteristics in the NS-LBP patients, and suggested that they would improve through respiratory exercises.

KEYWORDS

breathing, diaphragm, low back pain, respiratory muscle endurance, respiratory muscle strength, Malaysia

1 | INTRODUCTION

Non-specific low back pain (NS-LBP) is a major health problem encountered by physiotherapists and other medical professionals in daily clinical practice. Approximately 84% of people encounter low back pain (LBP) in their lifetime, with a prevalence of approximately 23% (Balagué, Mannion, Pellisé, & Cedraschi, 2012). Identifying the essential cause of a disability related to LBP is of top priority (Costa Lda et al., 2012). During the past few decades, respiratory involvement in the field of spinal health has been suggested as an important factor by a variety of models, such as the model of movement dysfunction, clinical puzzle integrated model, and multifactorial causative model for diagnosing and treating NS-LBP (Key, Clift, Condie, & Harley, 2008; Lee, 2011; Richmond, 2012). Even though a variety of models have been proposed, the constituents of respiratory involvement have not been tested thoroughly, but instead suggested through clinical observation (Key et al., 2008). Understanding the different components of respiratory pattern constituents among NS-LBP patients could provide an alternative approach to the examination and management of NS-LBP.

1.1 | Literature review

In view of identifying the undisputable cause of LBP, there is a growing body of literature that recognizes the importance of respiratory function and its association with this condition (Beeckmans et al., 2016; Janssens, Brumagne, Polspoel, Troosters, & McConnell, 2010; Janssens et al., 2013, 2015; Mohan, Paungmali, & Sitilertpisan, 2017b). The diaphragm is a dome-shaped muscle that descends like a parachute during inspiration, and it plays an important role in contributing to spinal stiffness through the influence of intra-abdominal pressure, mechanical effect, and attachments of the diaphragm crura

(Boyle, Olinick, & Lewis, 2010). Therefore, clinical instability in postural function of the diaphragm is thought to be an important cause of LBP (Panjabi, 2003).

Due to this instability, fatigue, and abnormal position of the diaphragm, postural dysfunction and impaired proprioceptive impulses have been reported among LBP patients (Brumagne, Janssens, Janssens, & Goddyn, 2008; Janssens, Brumagne, et al., 2013; Janssens, Pijnenburg, et al., 2013; Janssens et al., 2015; Kolar et al., 2012). Strength and endurance are components related to respiratory muscle function, which have been studied (Janssens et al., 2015). This is important, particularly for respiratory muscle function, as strength and endurance are considered conventional functions for performing activities optimally. That is, it is not known how a patient with LBP exhibits the strength and endurance components of respiratory muscle function.

In line with these studies, survey data from an Australian longitudinal research study on women's health inferred that breathing difficulties have a strong association with back pain when compared with physical activity and obesity (Smith, Russell, & Hodges, 2006). In addition, there has been increased interest in the area of breathing control among LBP patients, from which the authors concluded that patients who complete significant lowering and lifting tasks use more lung volume when compared to healthy participants (Hagins & Lamberg, 2011; Lamberg & Hagins, 2012).

Knowing clearly what type of breathing pattern this LBP population exhibits and how it is graded is challenging (Mohan, Paungmali, & Sitilertpisan, 2017a). It is also not known how to assess the breathing pattern or how far the diaphragm ascends and descends because of altered postural function caused by LBP. It is difficult to establish a potential link between respiratory characteristics of an individual with LBP. Therefore, there is a need to identify an appropriate association in respiratory characteristics that are known to cause LBP in order to enhance management options among LBP patients. How far these exchanges differ between patients with NS-LBP and normal individuals is an important variable for consideration. Consequently, in this study, we sought to understand the alteration in respiratory function in LBP patients. A desirable strategy is needed to test the appropriate function and performance in diagnosing and treating NS-LBP.

In order to test the above, an alternative approach that complements the diagnosis and treatment of NS-LBP has been proposed in past research. In the present study, a rule for appropriate function and performance was evidenced from the clinical puzzle model that relates to lumbo-pelvic and musculoskeletal dysfunctions (Lee, 2011; Lee, Lee, & McLaughlin, 2008). Therefore, this model was used to evaluate the paradigm for NS-LBP treatment (Lee, 2011; Lee et al., 2008).

1.2 | Aim

The objective of this study was to investigate the respiratory characteristics among individuals with and without NS-LBP. Respiratory muscle function (strength and endurance), diaphragm mobility, chest expansion, and core stability were explored among patients with NS-LBP and normal healthy individuals. The specific objective was to establish a correlation between respiratory function and other variables.

2 | METHODS

2.1 | Study design and setting

In this cross-sectional study, we recruited participants from a physiotherapy clinic of a public university in Malaysia.

2.2 | Participants

The inclusion criteria were NS-LBP patients aged between 18 and 55 years of age, diagnosed by a physician specializing in NS-LBP, and characterized for at least 6 months by mechanical pain (pain that worsens with movement and improves with rest) between the last ribs and gluteal sulcus (Brumagne et al., 2008; Lawand et al., 2015). At least three episodes over a 6-month period characterized symptoms of LBP (Janssens et al., 2015), with a pain intensity at the time of testing of between 2/10 and 5/10 according to the Numerical Rating Scale (NRS). The ratio of forced expiratory volume had a forced vital capacity (FEV1%) of >80% (Gibson et al., 2002). Healthy individuals were included as controls, providing they had no history of LBP over the previous 12 months.

Participants were excluded if they were pregnant or had chronic respiratory diseases, such as bronchial asthma, chronic obstructive pulmonary disease, or bronchitis (Janssens et al., 2015), or a history of surgery to the lumbo-sacral spine (Janssens et al., 2015) or numbness or neural signs in their leg(s). Light smokers (<1 pack or <15 cigarettes per day) and those subjects who smoked >100 cigarettes in their lifetime also were excluded. The primary outcomes considered in this study were respiratory muscle strength and endurance, and diaphragmatic mobility. Secondary outcomes were breathing pattern, chest expansion, and core stability. Permission to use the measurement instruments was obtained from the relevant authority prior to data collection.

Maximal inspiratory pressure (MIP) was a primary outcome considered for calculating the effect size (Janssens et al., 2015). The sample size was calculated using the G*power program 3.1.0 for two tails, and mean : difference between two independent means (2 groups). The estimated sample for obtaining a power of 80% minimum at a significant alpha level of 95% required a total of 34 participants with NS-LBP and another 34 as healthy controls.

2.3 | Ethical consideration

The study procedures were approved by the research ethics committee at Universiti Teknologi Mara (reference: REC/269/16). All of the participants provided written, informed consent prior to participation, and their details were confidentially maintained by assigning a code number for each participant during the procedures and analysis.

2.4 | Data collection

2.4.1 | Measurement tool and procedures

Numerical rating scale and oswestry disability index

Pain was rated using the NRS, in which all participants rated each pain on a 0–10 scale, and the Oswestry Disability Index (ODI) was used to ascertain the level of disability among the LBP patients.

Pulmonary function test

All of the participants were asked to perform three distinct maneuvers using a spirometer of forced vital capacity. Details, such as age, height, and weight, were calculated using the SECA weight and height scale. The interpretation was made as recommended in earlier guidelines (Gibson et al., 2002; Miller et al., 2005). The FEV1% indices were interpreted for both groups (LBP patients and healthy controls) in order to authenticate no active disease process of the respiratory system.

The participants were assessed for the following outcomes after screening for the selection criteria.

Total faulty breathing scale

The breathing patterns observed were scored using the Total Faulty Breathing Scale (TFBS). Details of the assessment, grading, and reliability measures have been previously published (Mohan et al., 2016).

Cloth tape measure

Measurements of chest mobility were carried out at the axilla, fourth intercostal, and xiphoid levels. An average of three readings were taken in centimeters, and the techniques of measurement proved to be reliable (Mohan et al., 2012).

Maximum voluntary ventilation

Maximum voluntary ventilation (MVV) measurements are a useful index for measuring respiratory muscle endurance, and were tested according to standard testing recommendations by asking all of the participants to inhale and exhale maximally for a period of 12 s while sitting and wearing a nose clip (Gibson et al., 2002; Miller et al., 2005; Wirth, Amstalden, Perk, Boutellier, & Humphreys, 2014). Spirometry assessments for respiratory muscle endurance were completed using a spirometer, which was calibrated prior to each testing session. The test was repeated three to five times, depending on the criteria of the American Thoracic Society and European Respiratory Society (Miller et al., 2005).

Respiratory muscle strength

Inspiratory and expiratory muscle strength were evaluated by measuring MIP and maximal expiratory pressure (MEP) using a respiratory pressure meter. The MIP was evaluated by instructing the LBP patients and healthy controls to exhale to residual volume, which is emptying the lungs and then inhaling forcefully against the MicroRPM with maximum effort for as long as possible for a minimum of 1 s (Wirth et al., 2014). The MEP was evaluated by instructing the patients to inhale to total lung capacity and then exhale forcefully against the MicroRPM with as much effort as possible (Wirth et al., 2014). Both techniques were repeated five times, and the best readings were taken as cm H_20 when sustained over a period of 1 s.

Diaphragmatic mobility

The B-Mode real time ultrasound device with 3.5 MHz convex transducer was used to detect diaphragmatic mobility (DM). A qualified person from a medical imaging department performed the test. Initially, the transducer was placed over the right subcostal region, with the striking angle of the ultrasound to the cranio-caudal axis in order to detect the left portal vein branch. Baseline values for each position were taken at this point by using the cursor, with all participants asked to perform the required breathing method to mark the second point. The distance between these two points corresponded to DM. This method of assessment has been considered reliable and valid (Mohan, Hashim, Md Dom, Sitilerpisan, & Paungmali, 2017; Toledo, Kodaira, Massarollo, Pereira, & Mies, 2003; Yamaguti et al., 2010).

Lumbo-pelvic stability

The pressure biofeedback unit (PBU) was used to detect core stability, and was initially pretested by loading the biofeedback unit cushion with 4 kg for 24 h, which ensured the accuracy of PBU measurements. The PBU unit was then placed under the lumbar spine L2–L4, with a pressure transducer pumped to 40 mmHg for monitoring the stability of the lumbo-pelvic position during different stability test levels (Paungmali & Sitilertpisan, 2012; Phrompaet & Paungmali, 2011). All of the participants were expected to maintain stability of the trunk, and if able to maintain a pressure gauge reading of 40 ± 4 mm of mercury (mmHg), they would achieve a pass category. However, those with a pressure gauge reading outside the target range would fail.

All of the measurements were carried out for the NS-LBP patients and healthy controls. Differences between the readings were evaluated through statistical measurements.

2.5 | Data analysis

The data were analyzed using SPSS version 21 statistical software. The SPSS data sheet imported all averaged data from a Microsoft Excel spreadsheet. The measurement of variables was subjected to descriptive and inferential analysis. Descriptions of demographic and study variables were presented as means, standard deviations, frequencies, and percentages. The independent *t*-test or Mann–Whitney *U*-test was used based on the assumption of normality. In addition, the effect size and Spearman's rank order correlation was computed for the study variables. The interpretation of effect size and correlation coefficient was estimated based on previously-published guidelines (Cohen, 1988; Portney & Watkins, 2009).

3 | RESULTS

Thirty four healthy participants (1 male and 33 females), with a mean age, weight, and height of 23.00 ± 1.57 years, 55.23 ± 13.63 kg, and 156.20 ± 5.07 cm, respectively, were matched with 34 LBP patients (1 male and 33 females) with a mean age, weight, and height of 23.00 ± 1.57 years, 58.38 ± 11.99 kg, and 155.44 ± 6.22 cm, respectively. There was no significant difference between demographic details, such as age, height, weight, and FEV1%, with $P > .05$. This signifies that there was no active disease process in the lungs based on ventilator parameters readings between the groups (FEV1%). The NRS revealed that the LBP patients had mild (n = 30, 88.2%) to moderate pain (n = 4, 11.8%). Similarly, the ODI showed minimal (n = 19, 55.9%) and moderate (n = 15, 44.1%) disability among LBP patients at the time of assessment.

Demographic details of the study variables are presented in Table 1. The DM ($P < .05$) values were lower in the LBP group when compared to healthy individuals, with a small effect size. This indicated that the respiratory parameter decreased in the LBP group. In contrast, MVV, MIP, and MEP values were not significant between the two groups ($P > .05$), with a negligible effect size. Similarly, there was no statistical difference in chest mobility at the axilla or xiphoid level, with a negligible effect size. This implies no difference in chest mobility readings. Nevertheless, there were statistically-significant values of chest mobility at the level of the fourth intercostal space ($P < .05$), with a moderate effect size.

TFBS analysis revealed that 8.8 % (n = 3) of healthy controls were predisposed to having a normal breathing pattern, followed by a mild faulty one in 91.2% (n = 31), whereas TFBS revealed that 23.5% (n = 8) of the LBP patients were prone to normal breathing, followed by a mild and severe faulty breathing pattern in 73.5% (n = 25) and 2.9% (n = 1), respectively. These findings signified that a majority of participants in both groups had a mild faulty breathing pattern, with $P > .05$. Lumbo-pelvic stability was measured through the PBU, which revealed that the healthy controls were able to achieve level 0 (n = 2, 5.9%), level 1 (n = 17, 50%), level 2 (n = 6, 17.6%), level 3 (n = 8, 23.5%) and level 4 (n = 1, 2.9%), whereas the LBP patients were able to achieve level 0 (n = 1, 2.9), level 1 (n = 12, 35.3%), level 2 (n = 12, 35.3%), level 3 (n = 7, 20.6%), and level 4 (n = 2, 50.9%). These findings signified that a majority of participants in both groups were between levels 0 and 2, with no statistically-significant difference ($P > .05$).

Fairly significant positive correlations of MIP and MEP to DM were found (r_s = .43, and r_s = .48, respectively). This suggested that when DM increases, respiratory muscle strength also increases. However, there was no relationship between respiratory muscle endurance and DM. Similarly, the chest mobility readings also showed no relationship to respiratory muscle endurance or strength. A significantly negative correlation was found only between the xiphoid level of chest expansion and respiratory muscle endurance. The lumbo-pelvic stability component exhibited fairly significant negative correlations with respiratory muscle endurance (r_s = .37), whereas respiratory muscle strength showed no relationship (Table 2).

4 | DISCUSSION

This study was undertaken to identify the potential existence of respiratory characteristics in individuals with chronic LBP and its association with the study variables. The results suggested that mobility of the diaphragm and respiratory muscle endurance was reduced in the NS-LBP group. In addition, they also revealed a relationship between respiratory muscle strength and mobility of the diaphragm among LBP patients.

Decreased DM, using real-time ultrasound among NS-LBP patients, was found in this study, and confirms the findings of an earlier study, in which the authors saw an abnormal position and a steeper slope of the diaphragm by using dynamic magnetic resonance imaging (Kolar et al., 2012). Interestingly, both studies researched LBP with different methodological strategies in order to ascertain the existence of respiratory impairment in LBP patients. Respiratory muscle endurance also reduced among LBP patients, with a small effect size, which indirectly substantiated earlier findings that suggested greater diaphragmatic fatigability in individuals with recurrent LBP (Janssens et al., 2013). However, both studies employed different methods to measure the level of respiratory impairment. The respiratory muscle strength measurement in MIP data (66 cm H_20) was not comparable to a previous study, as the MIP study values were higher (94 cm H_2O) among LBP patients (Janssens et al., 2015). However, the values of MIP and MEP were somewhat comparable to a study conducted on a healthy population in the same region (Johan, Chan,

TABLE 1 Demographic details of the study variables

Parameter	Controls Mean ± SD n = 34	LBP Mean ± SD n = 34	P-value (<0.05)*	Effect size (r)
DM (mm)	50.09 ± 9.18	45.09 ± 9.89	**.034***	.25
MVV (l/min)	119.46 ± 18.63	104.83 ± 29.36	.107	.29
MIP (cm H_2O)	60.00 ± 17.91	66.73 ± 17.70	.096	−.16
MEP (cmH_2O)	55.64 ± 12.07	58.02 ± 15.25	.478	−.10
Chest mobility (cm)				
1. Axilla	1.75 ± .44	1.61 ± .51	.267	.10
2. 4th ICS	1.33 ± .50	1.65 ± .49	**.010***	−.28
3. Xiphoid	1.57 ± .57	1.60 ± .68	.840	

*Significance of the bold values (P<0.05); DM, diaphragmatic mobility; ICS, intercostal space; LBP, low back pain; MEP, maximal expiratory pressure; MIP, maximal inspiratory pressure; MVV, maximum voluntary ventilation; SD, standard deviation.

TABLE 2 Correlation of respiratory parameters to other variables for low back pain

	MVV r_s (P<0.05)*	MIP r_s (P<0.05)*	MEP r_s (P<0.05)*
DM	.33 (.051)	**.43 (.011)***	**.48 (.004)***
Chest mobility			
1. Axilla	**.36 (.034)***	.06 (.733)	.31 (.070)
2. 4th ICS	−.30 (.079)	−.005 (.979)	−.06 (.715)
3. Xiphoid	**−.49 (.003)***	−.15 (.368)	.001 (.996)
TFBS	−.29 (.095)	.24 (.167)	−.011 (.950)
Core stability	**−.37 (.027)***	−.159 (.369)	−.03 (.866)

*Significance of the bold values (*P*<0.05); DM, diaphragmatic mobility; ICS, intercostal space; LBP, low back pain; MEP, maximal expiratory pressure; MIP, maximal inspiratory pressure; MVV, maximum voluntary ventilation; TFBS, Total Faulty Breathing Scale.

Chia, Chan, & Wang, 1997). The difference in values could be partly explained by alterations in the paraspinal muscle spindle and differences in the region of testing using different equipment. This further implies that respiratory characteristics are altered in LBP patients.

DM was found to be insufficient in NS-LBP patients, and was mostly associated with respiratory muscle strength. The potential mechanism for this association could be attributed to the clinical instability component of the diaphragm and anatomical derangement to the lumbar region (Boyle et al., 2010; Panjabi, 2003). In addition, the potential association of decreased mobility of the diaphragm could lead to decreased respiratory muscle strength, which can be related to decreased intra-abdominal pressure among LBP patients (Boyle et al., 2010). This is signified when participants are unable to generate optimal intra-abdominal pressure, which could lead to NS-LBP. Therefore, it is necessary to maintain optimal intra-abdominal pressure to control the lumbar spine.

No difference was found in the levels between the two groups for chest expansion, except in the fourth intercostal space among LBP patients. This could be determined by the difference in levels of physical activity between the groups, which was not considered in this study. Similarly, faulty breathing was observed in the majority of participants in both groups, which was expected, even in the healthy population, as previously evidenced (Mohan et al., 2016). It was interesting that only one LBP participant had a severe faulty breathing score when compared with normal healthy participants. This further supports the study hypothesis that LBP could alter breathing patterns and result in respiratory abnormality. The core stability component did not differ between the two groups in this study, and it showed a significantly negative correlation only with respiratory muscle endurance. This signifies that core stability is affected even in healthy participants.

4.1 | Limitations and recommendations for future research

The main limitation of this study was the limited age of the participants. The majority of the participants were female, which makes generalization of the results difficult. Furthermore, the measurement of DM using ultrasound was carried out extensively only on the healthy participants, as compared to the LBP patients, who required further exploration. The assessors and the participants were also challenged in monitoring, as well as avoiding compensations, when assessing with PBU. There were no normative data for comparing DM levels among LBP populations, which could vary in different regions of the study. Only one study identified the reliability of TFBS in healthy participants, and LBP and bronchial asthma patients. TFBS scoring in LBP populations would have been increased if the authors had taken the pain scale with additional severity into account when detecting abnormal breathing. In addition, the psoas major muscle, which has a spinal attachment with a diaphragm and is thought to have an impact on lumbo-pelvic instability, was not considered in the study. Therefore, these measures of outcome for assessing faulty breathing, and the psoas major muscle, need to be explored further.

The respiratory characteristics and facts explored in this study imply the involvement of respiratory constituents. These measures of outcome cannot be compared directly to other studies, but can be considered as a distinctive study in this area of research. Therefore, these measures of outcome can be recommended for future studies in preventing and exploring respiratory characteristics and generalizing study results in individuals with LBP (Fanello, Jousset, Roquelaure, Chotard-Frampas, & Delbos, 2002). In conclusion, these outcomes suggest that NS-LBP patients can make progress in respiratory muscle endurance, mobility of the diaphragm, chest expansion, and correcting faulty breathing. This can be achieved by correcting breathing through the ball and balloon exercise, thereby refining respiratory muscle endurance, chest expansion, and DM among NS-LBP patients (Boyle et al., 2010).

5 | CONCLUSION

This study has direct implications among health-care professionals, including physiotherapists, nurses, and physicians, who provide mental, social, and vocational measures to individuals with NS-LBP. These professionals play a significant role in reducing the impact of pain and other related issues among NS-LBP patients. By managing the variables explored in this study, outcomes can be improved for these individuals. The findings of this study showed an alteration in respiratory characteristics in NS-LBP patients when compared to healthy participants. They also suggested that NS-LBP patients can improve respiratory characteristics in components such as respiratory muscle endurance, mobility of the diaphragm, chest expansion, and correcting faulty breathing by education and respiratory exercises.

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AUTHOR CONTRIBUTIONS

Study design: V.M., A.P., and P.S.
Data collection: V.M., A.P., P.S., U.F.H., M.B.M., and T.N.N.
Data analysis: V.M., A.P., P.S., U.F.H., M.B.M., and T.N.N.

Manuscript writing and revisions for important intellectual content: V.M., A.P., and P.S.

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