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The Effect of Respiratory Exercises Integrated into Pulmonary Function in Patients with Lumbar Algo-Functional Syndrome

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Abstract: lumbar algo-functional syndrome associated with chronic low back pain is commonly linked to functional disability, altered postural control, and impaired trunk stability. Increasing evidence suggests that respiratory dysfunction and reduced diaphragmatic effi-ciency may contribute to these impairments; however, data regarding the specific impact of respiratory exercise programs on pulmonary function in this population remain lim-ited. Objective: this pilot study aimed to evaluate the effects of a structured respiratory ex-ercise program combined with conventional kinesiotherapy on pulmonary function in pa-tients with lumbar algo-functional syndrome, as well as its effects on pain intensity, lumbar mobility, and functional disability. Nineteen female patients (mean age 45.5 ± 14.8 years) diagnosed with chronic lumbar algo-functional syndrome participated in a six-week intervention (18 sessions) consisting of individualized conventional kinesiother-apy integrated with a progressive respiratory exercise program. Pulmonary function was assessed by spirometry (BIOPAC system), measuring tidal volume (TV), inspiratory and expiratory reserve volumes (IRV, ERV), inspiratory and expiratory capacities (IC, EC), functional residual capacity (FRC), total lung capacity (TLC), and measured and predicted vital capacity (VC). Clinical-functional outcomes included the Visual Analogue Scale (VAS), Oswestry Disability Index (ODI), and Schober test. Statistical analysis was per-formed using paired Student's t-tests, effect size estimation (Cohen's d), and Pearson cor-relation coefficients. Significant improvements in pulmonary function were observed, with a marked increase in tidal volume (+48.7%, $p = 0.007$) and expiratory capacity (+37.7%, $p = 0.002$), accompanied by a compensatory decrease in inspiratory reserve volume (−26.2%, $p = 0.001$). In parallel, clinically relevant improvements were recorded, including a 71% re-duction in pain intensity (VAS, $p < 0.0001$), an 11.9% increase in lumbar mobility (Schober test, $p < 0.0001$), and a 41.7% reduction in functional disability (ODI, $p < 0.0001$). Strong correlations were identified between key pulmonary parameters, particularly between to-tal lung capacity and vital capacity ($r = 0.97$, $p < 0.001$). The integration of respiratory exercises into conventional kinesiotherapy produced significant improve-ments in pulmonary function and clinical outcomes in patients with lumbar algo-functional syndrome. These findings support the inclusion of respiratory assessment and training in rehabilitation programs for chronic low back pain. Further randomized con-trolled trials with larger samples are warranted to confirm these preliminary results.

Keywords: chronic low back pain; lumbar algo-functional syndrome; respiratory exercises; pulmo-nary function; kinesiotherapy; rehabilitation.

1. Introduction

Lumbar algo functional syndrome is a one aspect of the algo functional syndromes that include a lot of clinical conditions characterised by hyperalgesia, allodynia, abnormal sensitisation of the central nervous system to pain, but we don'wihtout identify the presence of tissue or organic damage [1]. In this context in lumbar algo functional syndrome exists a dysfunction of multifidus muscle that are affected and this could be the start point of the non specific chronic low back pain. In this case the half functional syndrome includes multifidus muscle atrophy, fatty infiltration or abnormal muscle function [2].

In the present the literature have identified the main sectors of quality of life correlated with the health of persons affected by chronic pain [3].

Despite the evidence from recent literature which demonstrates as first line of treatment in chronic pain is the non-pharmacological intervention because the prescription of opioid medications is still common practiced and also prolonged bed rest and analgesic are common approach. In this sense, a correct management based on scientific evidence and adequate prophylactic interventions could lead to diminish the incidence of new cases and this is a fundamental aspect [4].

In the context of lumbar algo-functional syndromes and also in chronic low back pain, one of the problems which arises is respiratory function which is affected, due to prolonged immobilization periods and due to the limitation of global muscle activity and antalgic positions developed. The lumbar algo functional syndrome involves changes of respiratory function through paravertebral muscle rigidity, diaphragmatic dysfunction, compensatory breathing pattern and postural disfunctions.

Therefore, breathing exercises play a significant role in improve the life quality for patients affected by lumbar algo functional syndrome. By this way is possible to induce relax of overstrained muscles, restoring normal breathing patterns and improve the function of respiratory muscles.

In addition, these exercises increase intra-abdominal pressure, that is essential for improving lumbar stability.

However, previous reviews have not taken into account the diagnostic categories of lumbar algo functional syndrome, and some potentially relevant studies have been excluded.

Most studies, as Haiting and collaborators state, speak about core-type strengthening, addressed to the abdominal muscles, without giving attention to the diaphragm, maintaining trunk stability and postural control, aspects mentioned by Fatemeh et.al [5].

In the review carried out by Haiting it is mentioned that the activity of trunk muscles facilitates respiratory function but included the patients with non specific chronic low back pain [6]. Improvement of the strength and tone of deep abdominal and lumbar muscles in combination with breathing exercises is much more efficient in reducing pain than an unilateral approach which consists in core strengthening [7]. The analysis made by these authors concluded that a breathing exercise program of approximately 30–50 minutes, 3–5 times/week, reduces manifested chronic low back pain.

Controlled breathing allows the patient to develop a new level of perception and awareness of own body, deficient otherwise in chronic low back pain. The practice of controlled breathing seems to be expressly indicated in the management of chronic low back pain [8].

However, evidence-based research regarding the effectiveness of breathing exercises on back pain still miss according to Jiao [7]. The study of these authors showed, however, that there were improvement of the score visual analogue scale(VAS scale), ODI score, after 6 weeks.

McNarry et.al [8], mentioned that breathing exercises influence the function and morphology of the spine, statics and mobility through modulation of intra-abdominal pressure by contraction of the transversus abdominis and contraction of the diaphragm.

Moreover, breathing exercises produce adaptative changes at the level of muscle fibers which improve the strength of respiratory muscles and also facilitate strengthening of the muscles that have role in spine stability [9].

The study of Ying [10] and collaborators evaluates the combined effects of training for abdominal muscles and breathing exercises through various outcome evaluation measures, including pain intensity, lumbar function and strength of abdominal muscles. Thus, in the principles from which the authors started in drawing up the protocol for reducing low back pain, it was taken into account that core muscles strengthening has been observed to optimize the recruitment of deep muscles patterns such as transversus abdominis and multifidus, improving neuromuscular control and the dynamics of lumbar stability [10] and respiratory muscle training (RMT).

During stabilization exercises, the coordinated contraction of primary respiratory muscles and synergistic muscles, both in inspiration and in expiration, has been underlined. In addition, correct synchronization of breathing and application of adequate respiratory resistance can considerably reduce the pain in low back pain [11].

In their paper Youn-Jung and collaborators [12], referred to the importance of continuing research for consolidation the quality of evidence which supports respiratory interventions for non-specific chronic low back pain, including through randomized clinical studies which investigate the differences between the type, frequency and duration of respiratory movements.

Changes of respiratory characteristics have been reported in patients with non-specific low back pain. To date, there are few studies which analyze the effect of low back pain on pulmonary parameters.

Respiratory therapy is one of the exercise therapy and plays an important role in the treatment of non-specific chronic low back pain. The conclusion of the literature is that complex studies of evaluation the respiratory function are necessary in correlation with staging of non specific chronic low back pain, with recorded dysfunctions. The main problem of research addresses relationship between lumbar algo functional syndrome and respiratory function is whether chronic lumbar dysfunction changes breathing patterns and involved change of respiratory volumes. One of the gap in research addresses is that the respiratory function evaluation is not routinely integrated into lumbar pain evaluation, despite known anatomical and functional interdependence. Also insufficient quantitative and experimental evidence linking chronic low back pain (CLBP) with measurable pulmonary function changes; lack of integrative approaches combining respiratory muscle training with spinal stabilization strategies; weak mechanistic and correlational evidence between:pulmonary parameters,neuromuscular control,clinical severity of CLBP.

The rationale of this research is linked with the evaluation of pulmonary function that helps identify hidden impairments not captured by musculoskeletal assessment alone. Dysfunction of the diaphragm and associated respiratory muscles may therefore compromise postural control, reduce spinal stability, and perpetuate pain and functional disability. Despite this biomechanical and functional interconnection, pulmonary function assessment is not routinely included in the clinical evaluation of patients with low back pain. This represents a significant gap in current rehabilitation practice, as traditional musculoskeletal assessments may fail to detect underlying respiratory dysfunctions.

Clinical rationale includes also integrating pulmonary evaluation aligns with modern biopsychosocial rehabilitation approaches, based on pain assessment and functional assessment.The aim of our study is to make an objective assessment of the effectiveness of a breathing exercise program, using spirometry for respiratory function assessment, in the context of a combined rehabilitation program that includes breathing exercises combined with classical therapy for lumbar algo functional syndrome. The hypothesis are: specific breathing exercises intervention applied to patients affected by lumbar algo functional syndrome can lead to changes of respiratory parameters measured by spirometry and also improve of functional status. lumbar algo functional syndrome alters respiratory mechanics and muscle function. Breathing contributes to spinal stability and postural control. Respiratory interventions lumbar algo functional syndrome show measurable clinical benefits.

2. Materials and Methods

2.1.Participants

This study was carried out by the University of Craiova, Faculty of Physical Education and Sport (FEFS), Department of Kinesiotherapy and Sports Medicine, between July and October 2025. A sample of 19 participants (women) diagnosed with lumbar algo-functional syndrome in the context of chronic low back pain was recruited. All participants signed written informed consent and the approval of the Ethics Committee of FEFS was obtained 68/15.09.2024 and the research was carried out respecting the principles of the Declaration of Helsinki, 2013 version.

The inclusion criteria were the following:

- diagnosis of lumbar algo-functional syndrome in the context of chronic low back pain;
- pain more than 12 weeks;
- age between 25 and 55 years;
- pain intensity 5 or more according to the Visual Analogue Scale (VAS);
- the subjects participated consistently in the therapeutic program instituted.

The exclusion criteria were:

- subjects who presented radiculopathy with neurological symptoms;
- suspicion of vertebral canal stenosis;
- cognitive or psychiatric disorders;
- followed medication treatment of the type of infiltrations in the last 3 months;
- respiratory diseases history.

2.2. Evaluation of participants

The evaluation of the subjects included functional evaluation and evaluation of respiratory function.

- Clinical and functional evaluation

The assessment of functional capacity through the Oswestry Low Back Pain Disability Questionnaire [13], Quadruple Visual Analogue Scale[14], Schober test[15].

- VAS scale. The numerical scale of pain evaluation was used. Patients reported: the average pain in the last 48 hours and the pain induced by activities. It was recorded as determining factor the pain present during movement, based on the BPS scale (Back Performance Scale [16]) with 5 functional tasks. The participants evaluated the average level of pain after the 5 tasks.
- Oswestry Disability Index (ODI) to quantify the impact of low back pain on daily activities and on the functional capacity of the subjects.
- Schober test for segmental lumbar flexion.

- Evaluation of respiratory function

The evaluation of respiratory function was carried out with the help of BIOPAC Systems, BIOPAC Airflow Transducer, BIOPAC Bacteriological Filter (one per subject), BIOPAC Noseclip, Biopac Student Lab System, Computer System (Windows), with the module destined for exploration of respiratory function. The equipment contains a sensor for spirometry, mouthpiece, dedicated software and allows measurement of respiratory volumes. Guidelines according to Davis [17].

The recording was carried out after a prior preparation of the subjects, to whom it was explained the way in which they must cooperate during the recording. The recording procedure went through the following stages:

1. Recording the anthropometric parameters of the patient.

2. The calibration of the equipment is carried out according to standard procedures.

3. The recording is carried out:

- the subject relaxed in order to obtain an efficient measurement;
- the subject's clothing loose, so as not to restrict thoracic expansion;
- maintaining the Airflow Transducer in vertical and fixed position;
- each subject received own mouthpiece.

Preparation of the patient:

- subject seated, relaxed;
- maintaining the transducer vertical;
- before recording, the subject accommodated with normal breaths for 20 seconds.

The recording includes: - 5 cycles of normal breaths;

- deep inspiration then complete expiration; - 5 cycles of normal breaths. Stopping the recording, Figure 1.

Figure 1.– Method of measurement with the vertical airflow transducer

After stopping the recording, the software will automatically calculate the respiratory volumes. At the end of the calculation, the data appear on the screen.

The parameters measured were: tidal volume (TV) – the volume of air mobilized with each inspiration and expiration at rest, Inspiratory Reserve Volume (IRV) – the maximum amount of air which can be inspired starting from the end of a resting inspiration, Expiratory Reserve Volume (ERV) – the maximum amount of air which can be expired starting from the end of a resting expiration, Vital Capacity (VC) – the volume of air from the lungs in a maximal unforced expiration which follows a maximal inspiration, Functional Residual Capacity (FRC) – the volume of air contained in the lungs at the end of a resting expiration, Total Lung Capacity (TLC) – the volume of air contained in the lungs at the end of a resting expiration, Expiratory Capacity (EC), Inspiratory Capacity (IC).

The participants performed two testing sessions, at the beginning (T0) and at the end of the therapeutic program, after 6 weeks (T1).

2.3. Therapeutic intervention protocol

- Intervention

The patients followed a number of 18 sessions of individual conventional kinesiotherapy and respiratory kinetic program. The respiratory kinetic program was structured in 3 phases, each 50 minutes. The treatment was combined with traditional kinesiotherapy protocol specific for low back pain.

-Objectives of conventional kinetic program:

1. reduction of pain and paravertebral muscle contractures (main goal);
2. improvement of lumbar and pelvic joint mobility;
3. restoration of postural function;
4. re-establishment of the balance between flexor and extensor muscles of the trunk.

The therapeutic program included physiotherapy centered on stretching exercises, mobilizations, strengthening, stabilization and proprioception, clinically validated methods and adapted to the particularities of each patient.

All interventions were carried out in sessions of 50 minutes, performed 3 times per week, for 6 weeks.

-Objectives of respiratory kinetic program

1.optimization of breathing through diaphragmatic activation;
2.increase of thoracic mobility and of vital capacity;
3.training of coordination between respiratory movements and trunk mobility;
4.obtaining postural control through activation of the diaphragm, abdominals and pelvic floor;
5. reduction of low back pain before and after respiratory intervention.

The program was structured in three phases with the following progression: initial, intermediate and advanced.

-Phase I – Initial (weeks 1–2)

Objectives: awareness of breathing, activation of the diaphragm, mobilization of the thorax and relaxation of paravertebral musculature.

Submaximal effort.

Diaphragmatic breathing in supine lying: one hand supported on the thorax, the other on the abdomen, at the level of the umbilicus. Slow inspiration through the nose, feeling how the abdomen inflates and the hand on the abdomen rises, while the hand on the thorax remains motionless. Slow expiration, through the mouth, letting the abdomen deflate and the hand on the abdomen go down (inspiration 3 seconds – expiration 5 seconds).

Breaths with manual feedback. Supporting the palms laterally on the thorax, at the level of the rib border, and breathing so that, in inspiration, the palms move away, following the expansion of the transverse diameter of the thorax, and in expiration the palms come closer (3 sets x1 minute).

Lower rib mobilizations. Same technique as in the previous exercise, the difference being the positioning of the palms at the level of the lower ribs (laterally directed inspiration) (2 sets x 10 repetitions).

Deep inspiration, apnea, inflating the thorax, then slow expiration. Repetition of the movement of expansion and retraction (5 sets x 7 repetitions).

High thoracic breathing: supporting the palms in the upper part of the thorax and on the sternum, breathing so that the palms rise in inspiration and go down in expiration. In this way high thoracic breathing is made aware: the ribs rise anteriorly, increasing the anteroposterior diameter of the thorax (3 sets x 10 repetitions), Figure 2.

Figure 2. High thoracic breathing

-Phase II – Intermediate (weeks 3–4)

Objectives: integration of breathing with lumbar stabilization movements, increase of postural control and activation of abdominal musculature (transversus abdominis).

Moderate intensity.

For favoring abdominal breathing, thoracic expansion can be impeded by placing the upper limbs above the thorax and positioning a weight on the abdomen, such as a small sandbag. For optimal relaxation, we make sure that the tongue is positioned correctly, namely on the palatal vault, behind the upper incisors (3 setsx7 breaths)-Figure 3.

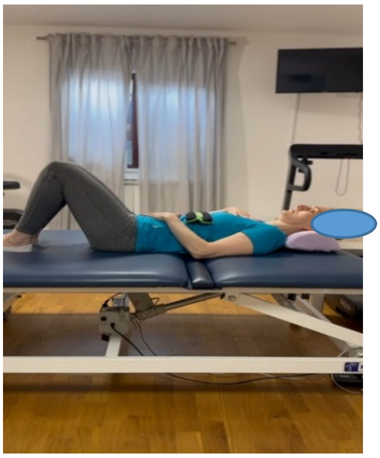

Figure 3. Control of abdominal breathing

Diaphragmatic breathing in standing with abdominal control (3 sets x 10 repetitions).

Synergistic activation diaphragm and transversus abdominis from quadruped position (3 sets x 10 repetitions)-Figure 4.

Figure 4. Synergistic activation diaphragm

Breathing coordinated with pelvic stabilization exercises. Pelvic lifts with support at the level of the feet and shoulders, with contraction of gluteus and posterior muscle chain (3 sets x 10 repetitions)-Figure 5.

Figure 5. Pelvic stabilization

Exercises with the therapy ball for acquiring respiratory control in unstable positions (3 sets x 12 repetitions).

-Phase III – Advanced (weeks 5–6)

Objectives: training of respiratory muscle endurance, integration of breathing in functional activities, optimization of thoraco-lumbar coordination.

Moderate–high intensity.

Direct stimulation of the diaphragm with resistance. The palms are placed laterally on the ribs board and follow their thoracic expansion in inspiration, then return in expiration. Resistance is opposed with the hands in inspiration, then, in expiration, the diaphragm relaxes (3 sets x 15 breaths).

Breathing exercises with rhythmic breathing associated with functional movements (lifts, controlled rotations) from supine lying and standing (3 sets x 10 repetitions). Figure 6, and Figure 7.

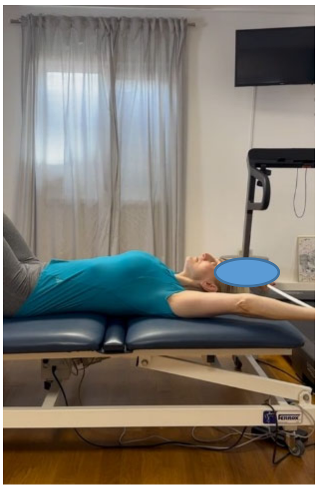

Figure 6. Coordination of inspiratory time

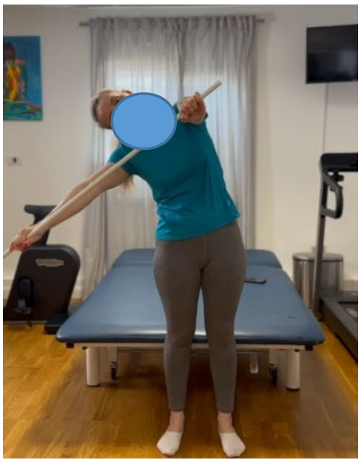

Figure 7. Coordination of expiratory time based

Dynamic stabilization exercises with respiratory control (3 sets x 10 repetitions).

Active global stretching and final relaxation exercises.

Summary of the kinetic program was thus structured:

- Phase I (weeks 1–2): Breathing awareness, diaphragm activation, thorax mobilization;
- Phase II (weeks 3–4): Integration breathing–lumbar stabilization, postural control;
- Phase III (weeks 5–6): Respiratory muscle endurance, thoraco-lumbar coordination.

2.4. Statistical analysis

The statistical analysis of the data collected was carried out using: The statistical analysis included descriptive statistics and a Student's t-test. The Student's t-test was applied to reveal any differences between parameter values from (T0) to second evaluation (T1). The test indicated whether there was a significant difference. We applied the Student's t-test [18] for equal means [19]. To analyze the effect size of the parameter evolution, we used the Cohen D coefficient [20]. The data were collected for the following parameters: TV, IRV, ERV, IC, EC, FRC, TLC, measured VC, predicted VC, ratio measured VC/predicted VC. For each parameter the initial and final mean values were calculated. The differences were tested statistically (t test for paired samples). Pearson correlation coefficients were calculated between initial and final values.

3. Results

The group of subjects formed of 19 women with lumbar algo-functional syndrome (average age 45.5 ± 14.8, average height 163.9 ± 6.1 cm).

3.1. Results of functional evaluation

Analyzing the results recorded during the functional evaluation that are presented in Table 1, we observed that there are spectacular improvements of all clinical parameters ($p < 0.0001$). Pain reduced by 71%, mobility increased by 11.9%, disability reduced by 41.7%.

Table 1. Evolution of functional evaluation parameters

Parameter	Before	After	p / Cohen's d
Schober test (cm)	15.75 ± 1.57	17.62 ± 1.31	p<0.0001 d=1.30 (large)
VAS (0-10)	6.16 ± 0.92	1.78 ± 0.87	p<0.0001 d=4.89 (very large)
Oswestry (%)	42.59 ± 3.53	24.84 ± 4.37	p<0.0001 d=4.47 (very large)

The effect is large, which suggests that the intervention has a strong impact on mobility. On pain, the effect is enormous, indicating a substantial clinical improvement. Very large impact on quality of life and functionality, as can also be seen in Figure 8.

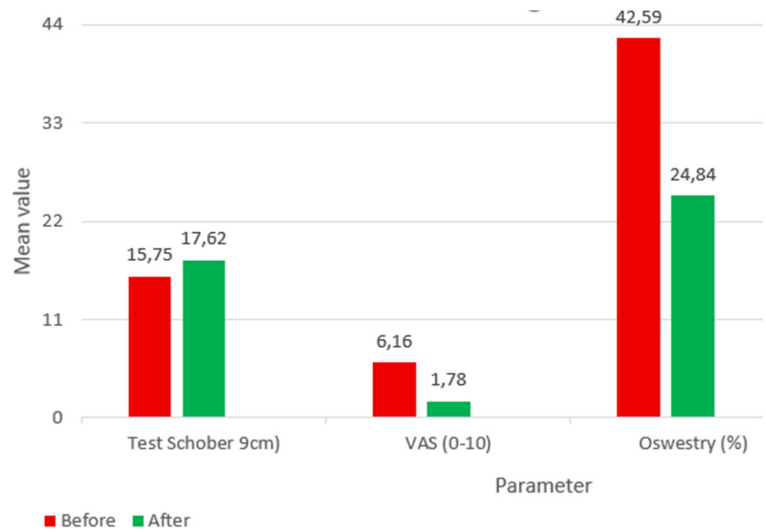

Figure 8. Graphical representation of the evolution of the values of functional evaluation tools

3.2. Results of respiratory function evaluation

Respiratory function was evaluated as mentioned previously, in resting conditions, considering such an evaluation important in order to estimate the effectiveness of the specific intervention program, which can ensure and improve the daily functional status of the patient with lumbar algo-functional syndrome.

The results are presented for each respiratory volume, at the initial moment T0 and final T1, separately in Table 2.

Table 2. Average values of respiratory parameters measured at the two moments T0 (initial) T1 (final)

Parameters	TV	IRV	ERV	IC	EC	FRC	TLC	Measured VC	Predicted VC	Measured VC/predicted VC [%]
Initial mean values	0.66	1.30	0.57	1.98	1.22	1.57	3.54	2.53	3.19	79.54
Final mean values women	0.97	0.96	0.71	1.93	1.68	1.71	3.64	2.63	3.19	81.96
Difference [%]	48.73	-26.24	25.01	-2.30	37.71	9.06	2.72	3.93	-	3.03
p*	**0.007**	**0.001**	0.139	0.525	**0.002**	0.139	0.370	0.401	-	0.533

* p < 0.005 Legend: TV – Average Tidal Volume; IRV – Inspiratory Reserve Volume; ERV – Expiratory Reserve Volume; IC – Inspiratory Capacity; EC – Expiratory Capacity; FRC – Functional Residual Capacity; TLC – Total Lung Capacity; VC – Vital Capacity

Relating the initial values of respiratory parameters to the reference values corresponding to the female gender we observe the following:

-TV = 0.66 L (normal value: 0.5 L), value 32% higher than normal, which means a deeper than normal breathing, possibly compensatory.

IRV = 1.30 L (normal value: 1.9 L), value 31.6% lower than normal, thus a significantly reduced inspiratory reserve.

-ERV = 0.57 L (normal value: 0.7 L), 18.6% lower than normal, with a slightly reduced expiratory reserve. Measured VC = 2.53 L (normal value: 3.1 L), 18.4% lower than normal.

The ratio measured VC/predicted VC = 79.54%, which means a vital capacity reduced below 80% of the expected value.

-TLC = 3.54 L (normal value: 4.2 L), 15.7% lower than normal, which means a reduced total lung capacity.

-FRC = 1.57 L (normal value: 1.8 L), 12.8% lower than normal and therefore a slightly reduced functional residual capacity.

The values of these respiratory parameters indicate an aspect which pertains to the development of a slightly restrictive breathing pattern, in which vital capacity is reduced, inspiratory reserve significantly diminished, tidal volume increased probably compensatorily and a reduced total lung capacity.

After involving the subjects in the specific kinetic therapy program, it is observed that a part of the parameters register statistically significant changes ($p < 0.05$), namely:

Average tidal volume (TV): significant increase (+48.73%), $p = 0.007$, indicates an improvement of the effectiveness of pulmonary ventilation, possibly as a result of the specific training and induce adaptations. Breathing became deeper and more efficient. These adaptations can be explained by relaxation of lumbar paravertebral muscles, improvement of compensatory chest rigidity, improvement of diaphragmatic mobility. In low back pain, breathing often becomes superficial (upper thoracic) due to muscle tension. The increase of TV demonstrates a "release" of the diaphragm, allowing deeper ventilation with a lower energetic consumption at rest.

Inspiratory Reserve Volume (IRV): significant decrease (-26.24%), $p = 0.001$. The decrease of IRV can be analyzed in the context of the increase of TV and this suggests that a part of this reserve is used to increase the volume inspired at every breath. It is probably a redistribution of inspiratory volumes, not a loss, and from clinical point of view correlates with the increase of TV which means a deeper, more ample breathing in resting conditions and in the unfolding of daily activities. Because the patients already have a deeper breath, the reserve available for a forced inspiration shrinks, indicate a new respiratory balance.

Expiratory Capacity (EC): significant increase (+37.71%), $p = 0.002$, the significant increase which reflects an improvement of expiratory capacity, supported by the increase of TV and ERV. The behavior of EC reflects a relax of accessory expiratory muscles, more complete and more efficient expiration, better elimination of residual air, improvement of pulmonary clearance. These results are due to the relaxation of abdominal and paravertebral muscles existing in the conditions of pain, but also restoration of mobility, and also a better involvement of abdominal muscles during the expiratory phase, which is essential for lumbar spine stability.

Parameters without statistically significant changes: ERV, IC, FRC, TLC, measured VC, measured VC/predicted VC – all have p values > 0.05, which indicates that the differences observed can be due to natural variation and not to a real effect.

-For ERV, although there is an increase, but this is not statistically significant. It can indicate a slight improvement of forced expiratory capacity. ERV reached practically normal value: 0.71 L (normal = 0.7 L), with an increase of 25% compared to the initial value of 0.57 L, and this is an improvement of expiratory capacity.

-IC remains practically unchanged, which suggests that changes of TV and IRV compensate each other. FRC presents a slight increase, but without statistical significance.

-TLC does not present statistically significant changes, practically it is unchanged, which suggests that the changes of the other parameters do not affect total lung capacity. VC has also a slight increase, without statistical significance, and if we report it to predictive values it is observed that there is an increase from the initial value: 79.54% to the final value: 81.96%.

The non-significant changes show tendencies of improvement for most parameters, but without sufficient statistical power (probably due to the small sample, n = 19).

Analyzing the relations and correlations between respiratory parameters the following aspects are observed:

The relation TV, IRV, ERV and EC shows that there is an increase of tidal volume (TV) which is associated with a decrease of inspiratory reserve (IRV), because a part of the air is used now at every breath. On the other hand, the increase of TV and ERV contributes to the increase of EC.

The relation between IC and FRC shows that IC (TV + IRV) remains stable because the increase of TV is compensated by the decrease of IRV. FRC (ERV + residual volume) increases slightly, reflecting a possible improvement of ventilation at pulmonary level.

The relation TLC and VC indicates that small changes of TLC and VC suggest that adaptations are rather functional than structural.

The ratio measured VC/predicted VC shows how close the real values are to the theoretical ones, and the slightly increase suggests an improvement of respiratory performance.

Pearson correlations between respiratory parameters are presented according to the definitions of Pearson correlation. The Pearson correlation coefficient (r):

- $r > 0.7$ = strong positive correlation
- $r = 0.4–0.7$ = moderate correlation
- $r < 0.4$ = weak correlation
- negative r = inverse correlation, and the results given in Table 3 demonstrate the existence of good positive correlations as follows:

Table 3 – Pearson correlations between respiratory parameters

Variables	TV	IRV	ERV	IC	EC	FRC	TLC	Measured VC	Predicted VC	VC m/VC p [%]
TV	1	-0.453	0.341	0.450	0.825	0.341	0.472	0.415	0.581	0.193
IRV	-0.453	1	0.120	0.592	-0.209	0.120	0.440	0.446	-0.006	0.564
ERV	0.341	0.120	1	0.428	0.812	1.000	0.822	0.820	0.448	0.766
IC	0.450	0.592	0.428	1	0.536	0.428	0.867	0.821	0.519	0.739
EC	0.825	-0.209	0.812	0.536	1	0.812	0.787	0.750	0.630	0.580
FRC	0.341	0.120	1.000	0.428	0.812	1	0.822	0.820	0.448	0.766
TLC	0.472	0.440	0.822	0.867	0.787	0.822	1	0.971	0.575	0.889
Measured VC	0.415	0.446	0.820	0.821	0.750	0.820	0.971	1	0.583	0.930
Predicted VC	0.581	-0.006	0.448	0.519	0.630	0.448	0.575	0.583	1	0.255
VC m/VC p [%]	0.193	0.564	0.766	0.739	0.580	0.766	0.889	0.930	0.255	1

Pearson correlations can explain the way in which the parameters influence each other, aspect which we have demonstrated using the t test to see whether these correlations are random or are statistically significant, of which the most relevant are the following:

- TLC and VC ($r = 0.971$; $p < 0.001$): This almost perfect correlation between total lung capacity and vital capacity shows that any progress of vital capacity generated an expansion of total pulmonary volume.

- TV and EC ($r = 0.825$; $p < 0.001$): A strong correlation which underlines that the improvement of tidal volume was supported by an increase of expiratory control capacity. This validates the effectiveness of the physiotherapy program through reduction of muscle tension and obtaining muscle symmetry.

- FRC and EC ($r = 0.812$; $p < 0.001$): Functional residual capacity (FRC) and expiratory capacity (EC) are closely related in this study, suggesting that the exercises influenced the volume of air which remains in the lungs after a normal expiration, improving dynamic stability of the trunk.

Conclusions of the correlations analysis between respiratory parameters are the following:

- There is a complex network of strong correlations between respiratory parameters;
- The strongest correlation is TLC–VC ($r = 0.971$), which validates the measurements;
- The negative correlation TV–IRV suggests a redistribution of respiratory volumes;
- All strong correlations are extremely statistically significant ($p < 0.001$).

The increase of TV and EC reflects a positive functional adaptation, the decrease of IRV is compensatory.

4. Discussion

The results obtained in context of application the respiratory program associated with the traditional kinetic program on patients with chronic low back pain demonstrate significant favorable effects on lumbar mobility, on pain perception and on the degree of functional disability. These results are according with the data reported in the recent literature, which support that controlled activity of deep respiratory muscles (diaphragm, transversus abdominis, lumbar multifidus) contributes to improvement of to reduction of low back pain and improve of respiratory function. The results obtained in the experimental group, characterized by significant reduction of pain (VAS), improvement of lumbar mobility (Schober) and decrease of disability degree (Oswestry), are in according with data published by Kim E et al [21], who demonstrated that inspiratory muscle training (IMT) applied to patients with chronic low back pain determines an increase of respiratory strength and a decrease of VAS scores. Also, Ahmadnezhad L. et al [22]reported significant improvements of respiratory function in patients with low back pain, confirming the favorable effects of combined respiratory and kinetic exercises. The results can be explained by the integration of respiratory components in kinetic exercises, which lead to a coordinated activation of deep stabilizing muscles (multifidus, transversus abdominis, diaphragm) and are presented also by the results of Janssens and collaborators [23] according to which respiratory training improves synchronization of diaphragmatic activity and reduces excessive intra-abdominal pressure, contributing to stability of the lumbar segment. Other studies [24, 25], showed that respiratory muscle training (RMT) can modulate autonomic activity, reducing sympathetic tone and pain perception. On the other hand, analyzing the literature we found that a series of recent meta-analyses are according to our results [26].

Dos Santos et al. [27], showed that lumbar stability exercises have a positive effect on pain and function in patients with chronic low back pain, but adding the respiratory component amplifies these benefits.

Regarding the behavior of respiratory parameters, it is necessary to make some discussions about the clinical implications: an increase of TV indicates a more efficient ventilation, which can lead to better blood oxygenation and increased effort capacity and tolerance, an aspect which, linked to the decrease of IRV. This means that a part of the inspiratory reserve volume can be used to support resting and effort breathing. Also this involves an increase the capacity to participate in the physical effort imposed by the specific exercise program. In parallel, the increase of EC proves the existence of an improvement of expiratory capacity, proved by the increase of ERV which signifies effectiveness of expiratory muscles and this is an important aspect in preventing the increase of residual air volume. The stability of the other respiratory parameters (IC, FRC, TLC, VC) indicates the existence of a functional stability and more than that, a development of the functional adaptation process.

Carrying out predictions through linear regression showed that there is a tendency of increase of TV, with a compensatory behavior of IRV.

The evolution of these parameters and especially the increase of TV are the results of combined therapy included the respiratory physical exercises and classical intervention destined to stabilization of paravertebral and abdominal muscles in lumbar pain syndrome. Physitotherapy program included diaphragmatic breathing exercises, controlled breathing, respiratory rehabilitation techniques, which also had as effect the improvement of oxygenation, reduction of muscle stress and muscle tension at trunk level; optimization of pulmonary function and an increase tolerance to effort but also reduce the sensation of fatigue. The mechanism involved is activation of the diaphragm which stabilizes the trunk and lumbar spine, because a superficial, incorrect breathing limited by the presence of pain can lead to overloading of lumbar muscles and maintenance of pain, aspect which is proved by the evolution of VAS scale, of mobility, of disability through improvement of postural control and trunk stability, as well as relaxation of lumbar muscles. In these conditions, monitoring the evolution of respiratory parameters as a result of integrating a respiratory re-education program into a recovery program destined to lumbar algo-functional syndrome can be useful in evaluate the progress and modulate the rehabilitation program. The approach of specific integrated training addressed to paravertebral muscles and respiratory muscles was carried out also by Garrido and collaborators [28] in their meta-analysis and they observed that there is a relation between postural control and expiratory muscle strength. This is edemonstrate through improvement of expiratory reserve volume, aspect also found in our research.

Park in his study [29], showed that a specific program conducted for 5 weeks, for low back pain in which he also integrated respiratory specific physiotherapy, obtained activation of the diaphragm parallel with lumbar stability and improvement of expiratory function, without increasing the activation of inspiratory muscles and thus implicitly an increase of inspiratory volume.

On the other hand, there are authors who mention that low back pain can generate inhibition of diaphragm activity, as primary breathing muscle [30]. Starting from Barr's observations, Bafi and collaborators in the article published in 2023 [31], mentioned that FEV1 volume is considerably decreased in patients with low back pain, decrease explained by the existence of weakness of the muscles core, respiratory, paravertebral muscles, in particular transversus abdominis and multifidus [32]. In this context pulmonary function is affected even in non-specific low back pain, compared to healthy persons, but the same authors underline the importance of evaluation respiratory function in basal conditions in order to design the intervention through physical exercises as prophylactic intervention. In the same sense the paper of Janssens and collaborators [33] raises the issue related to the way in which the strength and endurance of respiratory, underlining the necessity of exploring this aspect in persons with low back pain. Also Mohan and collaborators [33] explored respiratory dysfunction in persons with low back pain and observed that diaphragmatic mobility and respiratory muscle endurance are reduced, possibly due to the installation of muscle fatigue which affects both components, but maximal expiratory pressure (MEP) and maximal inspiratory pressure (MIP) values are comparable with those of healthy persons, aspects that are in according to our results regarding the evolution of VC. The fact that our results show that most of the measured respiratory parameters did not register statistically significant changes are also observed by Mohan. In the same time decreases of diaphragmatic mobility can lead to decreased respiratory muscle strength, of the thorax, and is related to decrease of intra-abdominal pressure in patients with low back pain, aspect noticed by Boyle and collaborators [34].

Carrying out a meta-analysis related to the effect of breathing exercises in low back pain, clinically functionally quantified, Shi and collaborators [35] observed that VAS and ODI scores have lower values, which signifies favorable evolution from the point of view of pain and functionality. Regarding respiratory volumes, our results indicated that lower values than normal values are recorded, aspect which can also be found in the meta-analysis of Martinez and collaborators [36] who highlighted a decrease of respiratory volumes, a decrease of respiratory muscle strength. The two synergists, the diaphragm and transversus abdominis, do not work properly in chronic low back pain and this also affect the function of the thoracolumbar fascia, creating a vicious circle because the action of the two synergists is limited even more [37], with limitation of respiratory function. In our study TV registered an increase after therapeutic intervention, under the conditions of an initial TV value above normal value associated with a low IRV, which decreases even more after therapeutic intervention. This aspect highlights the fact that there are compensatory mechanisms and this is mention in the paper of Hagins and collaborators [38]. The existence of muscle rigidity at lumbar level, of pain, represents a chall enge which can determine a slight increase of VC, as Hagins and collaborators also mention, aspect observed also by us through the increase of VC. Evolution of TV in our research means suggests early-stage adaptation,emphasize diaphragmatic breathing training, integrate breathing into functional movements. Clinical and practical implications of IRV evolution referee to encourage controlled breathing patterns and avoid overemphasis on maximal inspiration exercises. EC clinical and practical implications means improved ability to expel air, activation of abdominal and expiratory muscles, integrate expiration with core activation and breathing with stabilization exercises.

Concluded about the evolution of respiratory parameters we can explain the stability of these parameters and unchanged the values, means that exist preserved lung structure and also adaptation at a functional (muscular) level. The program emphasized: diaphragmatic breathing, coordination with trunk stabilization.These primarily influence: dynamic ventilation (TV, EC)rather than static volumes (TLC, VC).Significant findings of our research are some implicayion as follow: improved ventilatory efficiency Increased TV means deeper breathing and reduced need for compensatory shallow breathing. Better respiratory muscle function by involved abdominal muscle contribution during expiration. Non significant findings suggests early-stage adaptation**.**

Implications for Physical and Rehabilitation Medicine

-Reduced fatigue during physical activity
- Improved oxygen delivery
- Better tolerance to therapeutic exercise
- Enhanced trunk stability
- Control of intra-abdominal pressure and improved spine stabilization

5. Conclusions

Respiratory parameters are interdependent: the change of one (e.g., TV) directly or indirectly influences the other parameters. IRV significant decrease probably is a redistribution of inspiratory volumes, EC significant increase means more efficient expiration. ERV increases, but this is not statistically significant. IC remains practically unchanged. FRC presents a slight increase, but without statistical significance.

TLC does not present statistically significant changes. VC determined through measurements indicates a slight increase, without statistical significance, is an increase. Assessment of VC and TV can help to monitoring the evolution during therapy. The most important changes are present in dynamic respiratory parameters (TV, EC).

The causal relationship remains largely hypothetical and the rationale is well-justified but still exploratory.

Breathing exercises have an essential role in the rehabilitation of patients with lumbar algo-functional syndrome, positively influencing respiratory parameters, posture and trunk stability, but these are the results for a small group of participants and no control group.

Evaluation of respiratory function should be included in the standard protocol and we observe a feasibility of integrating respiratory exercises in CBLP management.

Spirometry helps detect subclinical dysfunctions.

Combining breathing exercises with trunk stabilization and postural exercises, especially in patients with lumbar algo-functional syndrome, in order to optimize both respiratory function and postural control, could an optim in limbar algo functional syndrome therapy approach

The observed correlations between respiratory variables highlight the interdependent nature of pulmonary parameters, but causal relationships cannot be established within the current study design.

Several respiratory parameters (e.g., TLC, VC, IC, FRC) did not demonstrate statistically significant changes, suggesting that the intervention may primarily influence functional (dynamic) rather than structural respiratory adaptations.

The decrease in inspiratory reserve volume appears to reflect a redistribution of respiratory volumes rather than a functional deficit, but further evidence is required to confirm this interpretation.

Limitations of the study

Our research is a pilot study that included a small number of participants and this involved a small number of data, which did not allow us to carry out a regression-type analysis and to create a prediction of evolution. In addition, the small number of participants does not allow us to generalize the results in the case of clinically more complex cases. There may be minimal errors of recording respiratory parameters, due to cooperation the patients.

One of the important limitation of our study is that we have not control group. In the same time our research included only female population that is also a limitation of the study. Further study will involve a control group and also a large group for make a large study and also explore muscle dysfunction also.

Inability to isolate the specific effect of respiratory exercises from conventional kinesiotherapy is also a limit of this study.

Limited external validity.

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Abbreviations

The following abbreviations are used in this manuscript:

TV	Tidal volume
IRV	Inspiratory reserve volumes
ERV	Expiratory reserve volumes
IC	Inspiratory capacities
EC	Expiratory capacities
FRC	Functional residual capacity
TLC	Total lung capacity
VC	Vital capacity
VAS	Visual Analogue Scale
ODI	Oswestry Disability Index
RMT	Respiratory muscle training
ADIM	Abdominal draw-in lumbar stabilization exercises
IMT	Inspiratory muscle training
RMT	Respiratory muscle training
CLBP	Chronic low back pain
MEP	Maximal expiratory pressure
MIP	Maximal inspiratory pressure

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