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Effect of pelvic floor muscle combined with pulmonary rehabilitation training on lung function in elderly patients after surgery for intertrochanteric fractures of the femur: a randomized controlled trial

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Abstract

Objective To explore the effects of pelvic floor muscle (PFM) combined with pulmonary rehabilitation training on diaphragm function and lung function in elderly patients with intertrochanteric fracture.

Methods This study was conducted by a randomized controlled single-blind method, 50 elderly patients with intertrochanteric fracture in Beijing Xiaotangshan Hospital were selected and divided into the combined training group (Experimental group, $n = 25$) and the lung function training group (Control group, $n = 25$) by the random number table method. Patients in the combined training group received pelvic floor muscle training combined with lung rehabilitation training, and patients in the lung function training group received lung rehabilitation training. Forced vital capacity (FVC), forced expiratory volume in the first second/FVC (FEV1/FVC) and peak expiratory flow (PEF) were evaluated before and after intervention to analyze the improvement of lung function. Diaphragm thickening fraction (DTF) and diaphragm excursion (DE) were used to observe the improvement of diaphragm function.

Results After 4 weeks of intervention, there were significant differences in lung function and diaphragm function between the two groups compared with the improvement before the intervention, but patients in the combined training group had more significant improvements in FVC, FEV1/FVC, PEF, DTF, and DE.

Conclusion Pelvic floor muscle combined with lung function training can improve the diaphragm function more significantly in elderly patients with intertrochanteric fracture after operation, and thus affect the lung function of patients.

Keywords Pelvic floor muscle training, Lung rehabilitation training, Intertrochanteric fracture, Diaphragm, Lung function

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Background

With the increase of age, the elderly are prone to osteoporosis or sarcopenia, so the incidence of fracture is also increasing, among which hip fracture is more common and has become a common problem faced by the elderly [1, 2]. Hip fractures currently occur in more than 10 million patients worldwide each year and are projected to exceed 20 million by 2050 [3, 4]. According to statistics, 20%–60% of patients need help to meet their daily life needs within 2 years after surgery, which seriously affects the quality of life of patients. Patients spend more than 40,000 US dollars in the first year after hip fractures, and the country needs to bear more than 17 billion US dollars in nursing costs every year, which brings a great burden to families and society [4, 5].

Surgical treatment is the preferred treatment for patients with hip fractures, but postoperative complications are often the direct cause of death in subjects with hip fractures. Among them, postoperative pneumonia (POP) is one of the common complications after hip surgery in subjects, with an incidence of 5.1–14.9%, and the mortality rate increases significantly to 27–43% after 30 days [6]. Therefore, reducing the risk, prevention and treatment of POP is the key to reducing mortality in hip fracture patients. At present, drug therapy and respiratory muscle training (abdominal breathing, lip contraction breathing, etc.) are widely used in clinical practice to enhance lung function.

However, it has been reported in the literature [7]that the coordination between the pelvic floor muscle and the diaphragm is poor in patients with pelvic floor muscle abnormalities. During inspiration, compared with healthy people, the thoracic elevation is higher and the diaphragm is lower. During exhalation, the chest drops, the abdominal wall is squeezed out, the pelvic floor muscles drop, and the auxiliary respiratory muscles are forced to compensate, resulting in an abnormal breathing pattern of shoulder-lifting breathing, which seriously affects the lung function and daily activity level of the patient. However, the relationship between pelvic floor muscle and diaphragm in patients after the intertrochanteric fracture has not been considered in current clinical practice. The pelvic floor muscle is composed of the anal levator muscle, coccygeal muscle, obturator muscle, urethral sphincter, anal sphincter and other muscles, which firmly support abdominal pelvic organs (such as the rectum, uterus, bladder, etc.) and plays a role in sealing the pelvic floor and keeping the organs in a normal position [8].

Massery et al. [9] confirmed through electromyography and ultrasound tests that diaphragm movement is significantly correlated with pelvic floor muscle function. The pelvic floor muscles contract eccentrically during inspirations and concentrically contract with abdominal muscles during forced expirations and coughing, thereby reducing abdominal volume and increasing intra-abdominal pressure (IAP). This forces the diaphragm up and increases the exhalation force. Some studies have shown that lung ventilation is closely related to pelvic floor muscle function. In studies observing the effect of PFM strong contraction on respiration, changes in forced lung capacity and forced expiratory volume are the main factors, which prove the improvement of lung function. Strong pelvic floor contraction during breathing contributes to diaphragm movement and makes it more effective [10, 11]. It was found that [12] PFM voluntary contraction intensity was incrementally positively correlated with forced expiratory flow, and PFM contraction intensity was positively correlated with FEV1. The co-contraction of PFM and anterolateral abdominal muscles promotes a correctly executed cough pattern [13]. Talasz et al. [14] conducted pelvic floor muscle training on patients, and the results showed that this program can increase internal abdominal pressure, and women suffering from stress incontinence will strengthen their expiratory muscles and ultimately improve their physical function. The correlation between PFM contraction intensity and forced expiratory flow may serve as a theoretical background for coordinating the potential role of abdominal and PFM training in expiratory flow-limited diseases.

Pelvic floor muscle and nerve injury in patients with intertrochal fracture after operation, as well as decreased strength of pelvic floor muscle and muscle relaxation in the elderly due to reduced hormone level, neurodegeneration, prostate disease, pregnancy, etc., seriously affect the function of pelvic floor muscle, and the balance of abdominal pressure maintained by diaphragm, abdominal muscle and pelvic floor muscle will also change. As a result, the static and dynamic function of the pelvic floor is abnormal, the internal abdominal pressure is abnormal, and the diaphragm function is limited, which directly affects the respiratory function of the patients [15, 16]. The ability to cough and expel sputum not only needs to keep the airway unobstructed and the diaphragm function normal, but also the function of the pelvic floor muscle is very important. Through spontaneous cough or cough reflex stimulation, the pelvic floor muscle and abdominal muscle contract, the diaphragm relaxes, and a certain internal abdominal pressure is maintained to promote the discharge of sputum and reduce the incidence of lung infection. Therefore, this study mainly conducted pelvic floor muscle combined with lung rehabilitation training or lung rehabilitation training for patients after intertrochanteric fracture of the femur to explore the effects of these two methods on the diaphragm and lung function.

Materials and methods

General information

This study was conducted by randomized controlled single-blind method. In this study, a randomized controlled trial was conducted to select postoperative patients with intertrochanteric fractures of the femur who were treated in Beijing Xiaotangshan Hospital from May 2024 to December 2024. A total of 50 patients were selected and randomly divided into two groups, namely the combined training group (Experimental group, $n = 25$) and lung function training group (Control group, $n = 25$), using the random number table method.

The inclusion criteria were as follows: (1) the hip fracture diagnosis criteria in the 2015 Chinese Guidelines for the Diagnosis and Treatment of osteoporotic fractures were met [17], and the intertrochanteric fracture of the femur was confirmed by CT/X-ray examination and treated with intramedullary nail surgery [18]. (2) 70 ≤ age ≤ 80 years old, stable disease, no serious cognitive impairment (MMSE score: illiterate > 17 points, primary school > 20 points, junior high school and above > 24 points). (3) After the first intramedullary nailing operation, the postoperative time was 1 week to 1 month. (4) Pelvic floor muscle strength ≥ II grade. (5) Patients without chronic obstructive pulmonary disease, interstitial pulmonary disease, pulmonary embolism and other organic pulmonary diseases. (6) Patients and their families are willing to accept pelvic floor muscle rehabilitation treatment and sign informed consent.

The exclusion criteria are as follows: (1) patients with diseases such as limb infection and tumor. (2) Patients with severe cardiovascular and cerebrovascular diseases (such as myocardial infarction, arrhythmia, heart failure, stroke, etc.) or other organ injuries. (3) Patients with severe cognitive impairment and communication disorder. (4) Patients who have received rectal or colon surgery and cannot fully cooperate with pelvic floor muscle strength testing and training. If one item is met, it is considered to be excluded.

Intervention measure

Both groups underwent routine rehabilitation training, including joint motion training, lower limb muscle strength training, balance training, walking training and daily rise life activity training. The patients in the lung function training group were added to lung rehabilitation training (lip contraction and abdominal breathing training, thoracic expansion training) on the basis of routine rehabilitation training; on the basis of the lung function training group, patients in the combined training group added pelvic floor muscle training (pelvic floor muscle combined with lip contraction–abdominal breathing training, pelvic floor muscle combined with chest expansion training), the specific methods are as follows:

(1) Lip contraction and abdominal breathing training [19]: The patient took the supine position, legs slightly apart, using the"nasal breathing and exhalation"way for breathing training, asked the patient to relax, slowly and deeply inhale through the nasal cavity for 2 to 3 s, and then hold the breath for 3 to 5 s when reaching the maximum lung capacity. When exhaling, the lips whistled and exhaled slowly for 3 to 6 s. The ratio of inhalation time and exhalation time was 1:2. When exhaling, the therapist can place one hand on the upper abdomen and exert inward force, and the patient can exercise the abdomen as much as possible during this process to reduce the activity of the chest. The therapist can remind the patient of the inspiratory and breathing process during the treatment. Respiratory rate 5 to 6 times/min, 10 min each time.

(2) Thoracic expansion training [20]: The patient is placed in a supine position with legs slightly apart and is asked to relax. The therapist can place both hands on both sides of the patient's chest, and the patient can inhale slowly and deeply through the nasal cavity for 2 to 3 s. During the inhalation, the patient can feel the expansion of the chest and the outer expansion of the ribs, hold the breath for 3 to 5 s at the end of the inhalation, and then slowly exhale through the mouth. On inhalation, the therapist applies downward and inward resistance, asks the patient to resist the resistance of the therapist's hand, and feels the ribs move downward and inward on exhalation. Respiratory rate 5 to 6 times/min, 10 min each time.

(3) Pelvic floor muscle combined with lip contraction and abdominal breathing training [19, 21]: The patient was placed in a supine position, legs slightly separated, and the patient was asked to relax, slowly and deeply inhaling through the nasal cavity for 2 to 3 s, then the abdomen swelled, and when the maximum lung capacity was reached, the pelvic floor muscle group was relaxed for 3 to 5 s; when exhaling, the lips whistled out slowly for 3 to 6 s. At this time, the therapist placed one hand on the patient's pelvic floor and guided the patient to contract the buttocks muscles, tighten the anus and perianal sphincter, and do anal lift exercises. The exercise continued for 2 to 6 s or quickly contract–relax the pelvic floor muscles while exhaling. When exhaling, the therapist can place one hand on the upper abdomen and exert inward force, and the patient can exercise the abdomen as much as possible dur-

ing this process to reduce the activity of the chest. Patients inhaled and exhaled 1 time for group 1, 5 to 6 groups/min, 10 min each time.

(4) Pelvic floor muscle combined with thoracic expansion training [20, 21]: The patient is supine, legs slightly apart, and is asked to relax. The therapist can place both hands on both sides of the patient's chest, and the patient can inhale slowly and deeply through the nasal cavity for 2 to 3 s. During the inhalation, the patient can feel the expansion of the chest and the outer expansion of the ribs, and hold the breath for 3 to 5 s at the end of the inhalation, at which time the pelvic floor muscle group is relaxed; then slowly exhale through the mouth, feel the ribs moving downward and inward while exhaling, contract the buttocks muscles, tighten the anus and perianal sphincter, and do anal lift exercises for 2 to 5 s, or quickly contract and relax the pelvic floor muscles while exhaling. Patients inhaled and exhaled 1 time for group 1, 5 to 6 groups/min, 10 min each time.

Measurements

Baseline leveling

Participants were measured at baseline before the intervention, including gender, age, fracture side, and Mini-Mental State Examination (MMSE).

Lung function index measurement

Lung function assessment: The portable lung function detector is made by Saike Medical Instrument Co, LTD (Model: X1), and the patient's head was raised 30° to 45° during each measurement. First, the instrument was calibrated. After the calibration, the patient was asked to cover the one-time bite with his lips and breathe normally for 4 to 6 cycles according to the instrument's instructions. Then, the maximum inhalation was followed by vigorous exhalation, and the lung gas was exhaled quickly and vigorously. The levels of FVC, PEF and one-second rate were measured, and the pulmonary function indexes such as FVC, PEF and FEV1/FVC were compared before and 4 weeks after intervention.

Indicators of diaphragm function

Diaphragm thickness (DT) assessment [22] (Fig. 1): Portable ultrasonic diagnostic instrument, manufactured by Hitachi Manufacturing Co, LTD (Model: EZU-HC1 C). Three parallel layers were seen on 2-D ultrasound, with two hyperechoic pleural and peritoneal layers and an echoless muscle layer in between [23]. The thickness of the diaphragm is the distance between the pleural and peritoneal layers. The thickness of the diaphragm

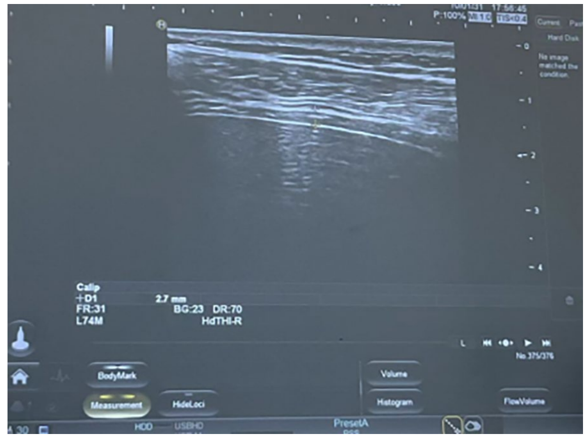

Fig. 1 Diaphragm thickness

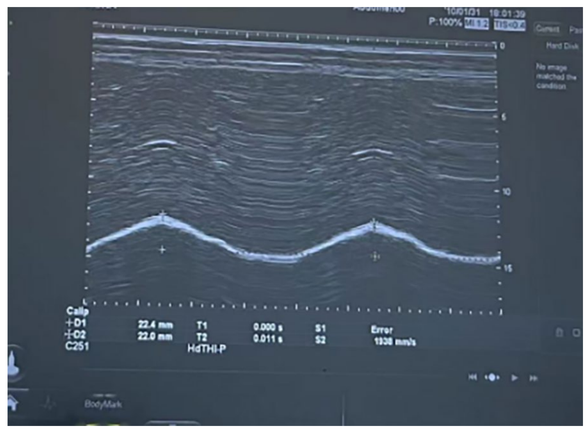

Fig. 2 Diaphragm excursion

during inhalation and exhalation can be obtained under ultrasound, that is, end-inspiratory diaphragmatic thickness, DTei and end-expiratory diaphragmatic thickness (DTee). The change in diaphragm thickness also reflects the contractility of the diaphragm and determines the diaphragm thickness fraction [24]. The specific formula is as follows: diaphragm thickening fraction (DTF) = (maximum diaphragm thickness at the end of inspiration—diaphragm thickness at the end of quiet expiratory breath)/diaphragm thickness at the end of quiet expiratory breath × 100%.

Diaphragm excursion (DE) evaluation [7] (Fig. 2): Portable ultrasonic diagnostic instrument, manufactured by Hitachi Manufacturing Co, LTD (Model: EZU-HC1 C). The vertical distance in which the diaphragm moves towards the liver during the inspiratory process is related to the expansion of the chest and the contribution of the diaphragm to respiration, reflecting the volume of airflow during inhalation. In ultrasonic M mode, the degree of diaphragm movement refers to the vertical distance between the position of the diaphragm raised at the end of expiratory breath and the position of the diaphragm lowered at the end of inspiratory breath [25].

The patient was supine and the diaphragmatic shift was recorded in M mode. The low-frequency convex probe is placed in the abdominal area below the right rib, between the longitudinal line and the midline of the axilla, with the liver as the acoustic window. Angle the probe so that the ultrasound beam is perpendicular to the back third of the right diaphragm. Diaphragmatic shifts between the end of exhalation and the end of inhalation were assessed based on M-pattern images and reported in millimeters. Take the average of the three subsequent measurements as the final value.

Hip function index

Hip function [26]: Hip function was assessed before and four weeks after treatment using the Harris Hip Function Rating Scale, which included pain, function, deformity, and range of motion, with a total score of 100. Scores above 90 were considered excellent, 80 to 89 good, 70 to 79 fair, and less than 70 poor.

Sample size calculation

The sample size was calculated using PASS software. The optimal test of the mean value of two independent samples is usually $\alpha = 0.05$, $\beta = 0.20$; according to the preliminary test in our hospital, the main outcome measures of forced vital capacity (L) where the mean value of the experimental group is 2.2, standard deviation is 0.28; mean of control group is 2.0, standard deviation 0.23. The sample size ratio of the two groups was 1:1, and according to the shedding rate <10%, the sample number was set as 25 cases in each group according to the above calculation method.

Statistical analysis

All data of elderly patients with intertrochanteric fractures after surgery in each group were included in SPSS 26.0 software for analysis, and the measurement data were tested for normality. If the data met normal distribution, the mean ± standard deviation was used to represent the data. If the data do not conform to the normal distribution, the median and quartile [M (P25, P75)] are used. The paired T-test (conforming to a normal distribution) or the Wilcoxon rank sum test (conforming to a non-normal distribution) were used to compare changes in each outcome measure before and after the intervention within each group. Comparison between groups variables was compared between the two groups using the independent sample T-test (conforming to normal distribution) or the Mann–Whitney U test (conforming to non-normal distribution). Counting data are expressed in frequency and percentage, and a Chi-square test is used. $P < 0.05$ for each index indicates a statistical difference.

Results

A total of 50 eligible patients were included in this experiment, including 25 patients in the pulmonary function training group and 25 patients in the combined training group. Among them, 1 patient in the lung function training group was transferred to the hospital due to personal reasons, and 2 patients in the combined training group were discharged in advance. There were no significant differences between the two groups in gender, age, affected side, cognitive impairment score (MMSE) and other general data ($P > 0.05$), and the baseline of patients in the two groups was basically the same and comparable (see Table 1).

Pulmonary function index

The comparison of pulmonary function indexes before and after intervention between the two groups is shown in Table 2.

Intragroup comparison: The pulmonary function indicators (FVC, FEV1/FVC, PEF) of patients in the lung function training group and the combined training group were significantly enhanced before and 4 weeks after intervention, with significant differences before and after intervention ($P < 0.001$). Comparison between groups: before the intervention, there was no significant difference in lung function indexes between the lung function training group and the combined training group. Four weeks after the intervention, the improvement of FVC and PEF in the combined training group was significantly different from that in the lung function training group ($P < 0.001$), and the improvement of FEV1/FVC was also

Table 1 General data characteristics

Groups	Number of cases	Sex Male/female	Affected side Left/right	Age(years)	MMSE score
Control	24	7/17	17/7	76.42 ± 3.84	25.00 ± 1.10
Experimental	23	7/16	15/8	75.43 ± 3.76	24.61 ± 1.37
P-value	/	0.925	0.680	0.381	0.286

Table 2 Comparison of pulmonary function indexes between the two groups before and after intervention

Index	Number of cases	Groups	Pre-intervention	Post-intervention	*P*-value
FVC(L)	24	Control	2.10 ± 0.19	2.82 ± 0.18*	< 0.001
	23	Experimental	2.17 ± 0.24	3.05 ± 0.18*▲	< 0.001
		P-value	0.309	< 0.001	
FEV1/FVC(%)	24	Control	61.67 ± 5.89	74.50 ± 4.85*	< 0.001
	23	Experimental	60.30 ± 5.56	79.04 ± 6.95*▲	< 0.001
		P-value	0.419	0.013	
PEF(L/S)	24	Control	1.63 ± 0.20	3.07 ± 0.30*	< 0.001
	23	Experimental	1.62 ± 0.21	3.65 ± 0.45*▲	< 0.001
		P-value	0.407	< 0.001	

* Indicates that there were significant differences between groups after and before the intervention, ▲ indicating that there were significant differences between groups compared with the combined training group

statistically significant compared with that in the lung function training group (P = 0.013 < 0.05).

Comparison of diaphragm function indexes

The comparison of diaphragm function indicators before and after intervention between the two groups is shown in Table 3.

Intragroup comparison: Patients in the pulmonary function training group and the combined training group were significantly enhanced in end-inspiratory diaphragmatic thickness, end-expiratory diaphragmatic thickness, diaphragmatic thickness index and diaphragmatic mobility before and after intervention for 4 weeks, with significant differences before and after intervention (P < 0.001). Comparison between groups: Before the intervention, there were no significant differences in diaphragmatic function-related indexes between the lung function training group and the combined training group. After 4 weeks of intervention, the improvement of DTei, DIF and DE in the combined training group was significantly different from that in the pulmonary function training group (P = 0.001 < 0.05, P = 0.001 < 0.05, P < 0.001), and there was no significant difference in DTee improvement between the two groups (P = 0.615 > 0.05).

Hip function

Intragroup comparison: Patients in the pulmonary function training group and the combined training group had significant differences in Harris scores before and after intervention and 4 weeks after intervention (P < 0.001). Comparison between groups: Before the intervention, there was no significant difference in Harris scores between the lung function training group and the combined training group (P = 0.056 > 0.05). After 4 weeks of intervention, there was no significant difference in Harris scores between the lung function training group and the combined training group (P = 0.171 > 0.05); see Table 4.

Table 3 Comparison of diaphragm function between the two groups before and after intervention

Index	Number of cases	Groups	Pre-intervention	Post-intervention	*P*-value
DTei(mm)	24	Control	2.54 ± 0.12	2.75 ± 0.13*	< 0.001
	23	Experimental	2.52 ± 0.12	2.90 ± 0.12*▲	< 0.001
		P-value	0.581	0.001	
DTee(mm)	24	Control	2.06 ± 0.10	2.17 ± 0.11*	< 0.001
	23	Experimental	2.09 ± 0.12	2.19 ± 0.13*	< 0.001
		P-value	0.368	0.615	
DTF(%)	24	Control	23.60 ± 5.83	26.98 ± 5.51*	0.001
	23	Experimental	20.95 ± 3.96	32.60 ± 5.50*▲	< 0.001
		P-value	0.07	0.001	
DE(mm)	24	Control	19.40 ± 0.97	22.89 ± 1.11*	< 0.001
	23	Experimental	19.63 ± 1.31	25.26 ± 1.03*▲	< 0.001
		P-value	0.502	< 0.001	

* Indicates that there were significant differences between groups after and before the intervention, ▲ indicating that there were significant differences between groups compared with the combined training group

Table 4 Comparison of Harris scores before and after intervention between the two groups, Unit: score

Index	Number of cases	Groups	Pre-intervention	Post-intervention
Control	24	45.83 ± 2.79	66.33 ± 2.85*	< 0.001
Experimental	23	44.30 ± 2.53	65.26 ± 2.39*	< 0.001
P-value		0.056	0.171	

* Indicates that there was a significant difference between post-intervention and pre-intervention comparisons within the group

Discussion

The mechanism of this study is mainly discussed from the synergistic relationship between the pelvic floor muscle and the diaphragm muscle. Currently, the two functions of the pelvic floor muscle are widely recognized: Support the pelvic organs and promote the closure of the urethra anus mechanism, but in recent years, studies have found that the pelvic floor muscle is not only a single role, but also a synergistic effect with other muscles, such as the pelvic floor muscle and abdominal muscle group, diaphragm together to form a muscle sac, known as the abdominal core. The diaphragm works in concert with the pelvic floor and abdominal muscles to maintain the dynamic balance of abdominal pressure and provide power during deep breathing and coughing [7, 27]. Recent studies have shown that during inhalation, the pelvic floor muscles contract eccentrically, concentrically with the abdominal muscles during forced exhalation and coughing, thereby reducing abdominal volume and increasing IAP, thereby forcing the diaphragm upward and enhancing exhalation [14]. Moreover, there is increasing evidence that abdominal muscle groups are involved in expiratory function to varying degrees [28]. At present, the improvement of respiratory muscle function mostly stays at the level of direct training of the respiratory muscle. Abdominal breathing, pursing lips breathing and other schemes can improve the muscle strength of the respiratory muscles, enhance the ability of cough and sputum excretion of patients, and remove foreign bodies in the respiratory organs, so as to improve the lung function of patients. However, studies [11, 29] have shown that patients with pelvic floor muscle abnormalities have abnormal coordination between pelvic floor muscles and diaphragm muscles, which affects the function of respiratory muscles and the ability to cough and expel sputum, and increases the possibility of pneumonia POP. The abdominal cavity can be regarded as an air sac, and the diaphragm and pelvic floor muscles are in a state of coordination. When normal people inhale, the diaphragm contracts downward, and the abdominal pressure increases, and then the pelvic floor muscles relax downward, and the internal abdominal pressure reaches a dynamic balance. When exhaling, the abdominal muscles contract, the pelvic floor muscles contract, and the abdominal pressure increases, which promotes diaphragmatic relaxation and upward movement, and promotes the function of the respiratory muscles and the ability to cough and expel sputum [9]. When the diaphragm is out of coordination with the pelvic floor muscle, the pelvic floor muscle function is reduced, resulting in the contraction of the anterolateral abdominal muscles and forcing the relaxed diaphragm up during forced exhalation and coughing, and the pelvic floor muscle is down, and the rise of the diaphragm is weakened, which is not conducive to the improvement of respiratory muscle function and lung function [7]. Therefore, respiratory muscle training should also consider the relationship between abdominal pressure and pelvic floor muscles.

The results of this study show that pelvic floor muscle combined with lung rehabilitation training and lung rehabilitation training can improve lung function in patients after intertrochanteric fractures of the femur. Abdominal breathing [30] is mainly based on training patients'diaphragmatic contractile and diastolic ability. During inhalation, diaphragmatic muscle fully decreases and thoracic volume increases, resulting in an increase in pulmonary ventilation volume. Lip contraction breathing [31] can increase airway resistance during breathing, prevent premature collapse of small airways during exhalation, and the inspiration–exhalation time is 1:2, which increases the exhalation time and reduces the fatigue of respiratory muscle. Thoracic expansion training[20] through the joint participation of various respiratory muscles to complete breathing exercises, on the one hand, the muscle strength of auxiliary respiratory muscles can be enhanced; on the other hand, adequate thoracic movement can increase the chest capacity, which is conducive to the improvement of lung ventilation function of patients. Some studies have shown that [32] breathing training can effectively improve lung function and reduce the incidence of POP in elderly patients with hip fractures. This study shows that lip-abdominal breathing and thoracic expansion training have significant differences in the improvement of FVC, one-second rate and PEF in patients with intertrochanteric fracture after surgery ($P < 0.05$). It is consistent with the research results of other scholars [31, 33].

At present, the results of this study showed that pelvic floor muscle combined with pulmonary rehabilitation training was superior to pulmonary rehabilitation training in improving the pulmonary function of patients after intertrochanteric fracture surgery, and there were significant differences in FVC, one-second rate and PEF between the two groups after 4 weeks of intervention ($P < 0.05$). According to Li et al. [34], there is a negative correlation between urinary incontinence and respiratory function, and lung disease will bring additional health burden, which is consistent with the results of this study. The main reason for this result may be due to the coordination between the diaphragm and the pelvic floor muscle. When the diaphragm and the pelvic floor muscle are in harmony, the diaphragm contracts downward during inspiration, and the abdominal pressure increases, and then the pelvic floor muscles relax downward, and the internal abdominal pressure reaches a dynamic balance. When exhaling, the abdominal muscles contract, the pelvic floor muscles contract, and the abdominal pressure increases, which promotes diaphragmatic relaxation and upward movement, and promotes the function of the respiratory muscles and the ability to cough and expel sputum. However, when there is no coordination between the diaphragm and the pelvic floor muscle, the diaphragm contracts downward during inhalation. However, the abdominal pressure becomes smaller due to the relaxation and weakness of the pelvic floor muscle [11, 14]. Therefore, the abdominal pressure cannot be increased due to the weak contraction of the pelvic floor muscle as the expiratory muscle during exhalation, so that the ascending force of the diaphragm is reduced [29]. Thus, for patients after intertrochanteric fracture of the femur, the pelvic floor muscle injury will inevitably lead to reduced abdominal pressure, and the imbalance between the diaphragm and pelvic floor muscle will also occur. Sinir et al. [13] conducted pelvic floor muscle training for women with stress urinary incontinence, and the results showed that the strength of the patients'respiratory muscles was strengthened. The findings support the hypothesis that expiratory muscle contraction during sneezing or coughing causes a rapid increase in IAP, which pulls the diaphragm and raises the IAP, leading to a high expiratory flow rate. In this study, patients in the combined training group showed a more significant improvement in PEF than those in the lung function training group, indicating that the maximum flow rate generated during forced exhalation was greater, indirectly indicating that the patients had stronger diaphragm strength. Some studies [12]claimed that the contraction intensity of pelvic floor muscle was positively correlated with forced expiratory volume within 1S, which was also verified in the results of this study.

This study mainly evaluated the changes in patients'diaphragm function by measuring DTei, DTee, DTF, and DE. DTei refers to the thickness of the diaphragm after contraction. When the body inhales, the diaphragm fibers become shorter and thicker due to the contraction of the diaphragm, which can directly reflect the contraction degree of the diaphragm; DTee refers to the thickness of the diaphragm at the end of breathing. Under normal circumstances, the diaphragm is in a dilated state at the end of exhalation, and the thickness of the diaphragm is thin at this time, which can reflect the degree of relaxation of the diaphragm. When the DTee is thin, it may indicate pulmonary diseases such as emphysema; when the DTee is thick, it may indicate that the patient may have diaphragm spasm, fibrosis and other disorders. DTF refers to the diaphragm thickness index, which mainly reflects the change of diaphragm thickness in the human body during breathing, and can best reflect the contraction ability and functional status of the diaphragm before and after a person [35]. Studies have shown that [36]DTF is positively correlated with respiratory function, and can be used as an indicator to predict the lung function of patients. DE refers to the range of diaphragm movement in the breathing process, which can reflect the ventilation of the lungs. When the diaphragm falls during inhalation, the chest volume increases and gas enters the lungs. Therefore, a larger diaphragm movement reflects the better ventilation function of the patient [37].

The results of this study showed that there were significant differences in DTei, DTee, DTF and DE between the combined training group and the lung function training group before and after intervention ($P < 0.05$), indicating that the combination of pelvic floor muscle and lung rehabilitation training is conducive to the improvement of diaphragm function. In both groups, patients were required to perform lip-abdominal breathing training and thoracic expansion training. Abdominal breathing mainly emphasizes the ability to train the diaphragm as the main respiratory muscle, strengthen the contraction ability of the diaphragm, reduce the overuse of auxiliary respiratory muscle, correct the wrong breathing pattern, so as to promote the cough and expectoration ability of patients after the operation of intertrochanteric fracture of the femur, and reduce the occurrence of POP, breathe out gently with abdominal breathing, avoiding exhaling for too long to avoid bronchospasm from the next inhalation[38]. Lip contraction breathing can prolong the time of exhalation, so that the diaphragm has a longer time to relax, and promote the rhythm of breathing. Thoracic expansion training can enhance the degree of thoracic motion, provide more space for the diaphragm to move, better coordinate the auxiliary respiratory muscle with the diaphragm, and increase the degree of diaphragm movement. The results obtained in this study are in agreement with the theory.

Four weeks after the intervention, the improvement of DTei, DTF and DE indexes between the two groups showed significant differences. Pelvic floor muscle training was performed on patients who underwent intertrochanteric fracture of the femur in the combined training group to restore pelvic floor muscle strength and improve the function of pelvic floor muscle. When the patient exhales, the contractility of the pelvic floor muscles increases and the abdominal pressure increases, which further promotes the upward relaxation of the diaphragm and thus improves the DE. Anal lift exercises are usually combined with proper breathing patterns, such as abdominal breathing. In the process of pelvic floor muscle combined with lung rehabilitation training, the movement of the diaphragm increases, making the diaphragm contract more fully during inhalation. Long-term abdominal breathing combined with pelvic floor muscle training may cause the diaphragm muscle fibers to get more exercise, resulting in an increase in DTF. However, it was found that DTF increased mainly because the DTei increased more significantly in the combined training group, and there was no significant difference in DTee between the two groups ($P = 0.615$). After intervention, the DTee of the patients in the combined training group was 2.19 ± 0.13, and that of the lung function training group was 2.17 ± 0.11. Perhaps due to the short training time, a large number of motor units were recruited during contraction, and the thickness of the diaphragm increased. During diastole, the improvement of nerve recruitment capacity did not lead to significant changes in muscle structure during diastole.

Limitations and innovations

In this study, abdominal pressure balance was restored through pelvic floor muscle training to promote the improvement of diaphragm function and further enhance lung function. However, the abdominal pressure index was not evaluated in this study, and a urine dynamic test was required for this evaluation in Beijing Xiaotangshan Hospital. Considering the safety and comfort of patients, the test was not conducted. This research in the prophase project (BeijingHospitalsAuthority Youth Programme, code: QML20192201) in conclusion: pulmonary rehabilitation training for the curative effect of pulmonary function in patients with hip fracture surgery is better than that of blank control group. On the basis of this subject, this study discussed the effects of pelvic floor muscle combined with lung rehabilitation training and conventional rehabilitation methods (lung rehabilitation training) on diaphragm function in patients with pelvic floor muscle injury after hip fracture surgery, and compared the two programs to restore lung function, which is the innovation of this experiment, so it is not necessary to add a control group that did not receive any rehabilitation training.

Conclusion

This study shows that pelvic floor muscle combined with lung rehabilitation training is superior to lung rehabilitation training in improving lung function in patients with intertrochanteric fracture after operation. Moreover, it was verified that the combination of pelvic floor muscle and pulmonary rehabilitation training promoted the improvement of pulmonary ventilation by improving the patients'diaphragm function (DTei, DTF, DE), thereby reducing the occurrence of POP.

Abbreviations

PFM	Pelvic floor muscle
FVC	Forced vital capacity
PEF	Peak expiratory flow
DTF	Diaphragm thickening fraction
DE	Diaphragm excursion
POP	Postoperative pneumonia
DTei	End-inspiratory diaphragmatic thickness
DTee	End-expiratory diaphragmatic thickness
IAP	Intra-abdominal pressure

Author contributions

J and F proposed the original idea, protocol development and interpretation, data analysis and data collection, and drafted all parts of the manuscript. W, J, T performed data collection, data extraction, and contributed to the development of the study protocol. All the authors approved the final manuscript.

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Data availability

Data is provided within the manuscript or supplementary information files.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Beijing Xiaotangshan Hospital, China (Approval number: 2024 Lunxun No. 11), and all subjects signed informed consent before treatment.

Competing interests

The authors declare no competing interests.

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References

1. Kim C-H, Kim K, Kim JW. Comparison of surgical outcomes for hip fracture between older patients with and without cancer: a propensity score matching analysis. Sci Rep. 2024;14:5406.
2. Meng Y, Liu Y, Fu M, Hou Z, Wang Z. Clinical characteristics of elderly hip fracture patients with chronic cerebrovascular disease and construction of a clinical predictive model for perioperative pneumonia. Orthop Traumatol: Surg Res. 2024;3:103821.
3. Sing C, Lin T, Bartholomew S, Bell JS, Bennett C, Beyene K, et al. Global epidemiology of hip fractures: secular trends in incidence rate, post-fracture treatment, and all-cause mortality. JBMR. 2023;38:1064–75.

4. Emmerson BR, Varacallo M, Inman D. Hip Fracture Overview. StatPearls. Treasure Island (FL): StatPearls Publishing; 2024.
5. Dyer SM, Crotty M, Fairhall N, Magaziner J, Beaupre LA, Cameron ID, et al. A critical review of the long-term disability outcomes following hip fracture. BMC Geriatr. 2016;16:158.
6. Tong X, Ci C, Chen J, Sun M, Zhao H, Wei H, et al. Incidence and risk factors for postoperative nosocomial pneumonia in elderly patients with hip fractures: a single-center study. Front Surg. 2023;10:1036344.
7. Hwang U, Lee M, Jung S, Ahn S, Kwon O. Effect of pelvic floor electrical stimulation on diaphragm excursion and rib cage movement during tidal and forceful breathing and coughing in women with stress urinary incontinence. Medicine (Baltimore). 2021;100: e24158.
8. Emerich Gordon K, Reed O. The role of the pelvic floor in respiration: a multidisciplinary literature review. J Voice. 2020;34:243–9.
9. Massery M, Hagins M, Stafford R, Moerchen V, Hodges PW. Effect of airway control by glottal structures on postural stability. J Appl Physiol. 1985;2013(115):483–90.
10. Thompson JA, O'Sullivan PB, Briffa NK, Neumann P. Differences in muscle activation patterns during pelvic floor muscle contraction and Valsalva manoeuvre. Neurourol Urodyn. 2006;25:148–55.
11. Neumann P, Gill V. Pelvic floor and abdominal muscle interaction: EMG activity and intra-abdominal pressure. Int Urogynecol J Pelvic Floor Dysfunct. 2002;13:125–32.
12. Talasz H, Kalchschmid E, Kofler M, Lechleitner M. Effects of multidimensional pelvic floor muscle training in healthy young women. Arch Gynecol Obstet. 2012;285:709–15.
13. Abidi S, Ghram A, Ghroubi S, Ahmaidi S, Elleuch MH, Girard O, et al. Impact of urinary incontinence on physical function and respiratory muscle strength in incontinent women: a comparative study between urinary incontinent and apparently healthy women. J Clin Med. 2022;11:7344.
14. Talasz H, Kofler M, Kalchschmid E, Pretterklieber M, Lechleitner M. Breathing with the pelvic floor? Correlation of pelvic floor muscle function and expiratory flows in healthy young nulliparous women. Int Urogynecol J. 2010;21:475–81.
15. Cao M, Pan L, Sun C, Sun C. Effect of biofeedback therapy combined with pelvic floor muscle training on the rehabilitation of pelvic floor muscle strength and urination function in elderly patients after femoral neck fracture. JWMC. 2022;41:86–8.
16. Lin S, Huang Q, Wang D. Effect of different pneumoperitoneum pressure on respiratory function in patients undergoing laparoscopic surgery. F J Med. 2014;36:10–2.
17. Qiu G, Pei F, Hu X, Tang P, Xue Q, Yang H, et al. Chinese Guidelines for the Diagnosis and Treatment of osteoporotic fractures (full text)(Principles for the diagnosis and treatment of osteoporotic fractures). CJJS. 2015;9:795–8.
18. Huang LX, Guo JJ. 2011 National institute for health and clinical excellence guidelines for adult hip fracture and evolution of treatment concepts for intertrochanteric femoral fractures. CMFJ. 2012;4:66–9.
19. Seo K, Hwan PS, Park K. The effects of inspiratory diaphragm breathing exercise and expiratory pursed-lip breathing exercise on chronic stroke patients' respiratory muscle activation. JPTS. 2017;29:465–9.
20. Xie W, Tan J, Ai J, Wu J, Peng J. Effect of early active respiratory circulation technique on aspiration in patients with dysphagia after partial laryngectomy. JASD. 2024;32:129–33.
21. Chen H, Yang N, Yang H, Huang G, Zhou W, Ying Q, et al. Efficacy of Kegel exercises combined with electrical stimulation on the restoration of postpartum pelvic floor muscle function. Am J Transl Res. 2023;15:622–9.
22. Boussuges A, Rives S, Finance J, Brégeon F. Assessment of diaphragmatic function by ultrasonography: current approach and perspectives. World J Clin Cases. 2020;8:2408–24.
23. Boon AJ, Harper CJ, Ghahfarokhi LS, Strommen JA, Watson JC, Sorenson EJ. Two-dimensional ultrasound imaging of the diaphragm: Quantitative values in normal subjects. MN. 2013;47(6):884–9.
24. Laghi FA, Saad M, Shaikh H. Ultrasound and non-ultrasound imaging techniques in the assessment of diaphragmatic dysfunction. BMC Pulm Med. 2021;21:85.
25. Palkar A, Narasimhan M, Greenberg H, Singh K, Koenig S, Mayo P, et al. Diaphragm excursion-time index: a new parameter using ultrasonography to predict extubation outcome. Chest. 2018;153:1213–20.
26. Giai Via R, Giachino M, Elzeiny A, Cipolla A, Marino A, D'Amelio A, et al. Reconstruction of unfixable comminuted posterior wall acetabular fractures with autologous bone graft: a systematic review. J Orthop. 2025;63:21–6.
27. Casey EK, Temme K. Pelvic floor muscle function and urinary incontinence in the female athlete. TPSM. 2017;45:399–407.
28. Constantinou CE, Govan DE. Spatial distribution and timing of transmitted and Reflexly generated urethral pressures in healthy women. J Urol. 1982;127:964–9.
29. Talasz H, Kremser C, Kofler M, Kalchschmid E, Lechleitner M, Rudisch A. Phase-locked parallel movement of diaphragm and pelvic floor during breathing and coughing-a dynamic MRI investigation in healthy females. Int Urogynecol J. 2011;22:61–8.
30. Hamasaki H. Effects of diaphragmatic breathing on health: a narrative review. Medicines. 2020;7:65.
31. Jiang S, Han J, Wang Y, Fei L, Zhang J, Wang Y, et al. Design and application of assisted lip contraction breathing training tool in home pulmonary function rehabilitation of patients with chronic obstructive pulmonary disease. CJRM. 2024;39:821–7.
32. Zhang Y, Wang H, Fan MJ, Fan L, Wang M. The application of different breathing training methods in elderly patients with femoral neck fracture a prospective, randomized, and single-blind study. Research Square. 2021. https://doi.org/10.21203/rs.3.rs-958980/v1.
33. Fu S, Deng X, Li Y, Fu Y, He L. The influence of pulmonary rehabilitation training based on hope theory on hope level and self-care ability of COPD patients. JN. 2024;39:111–5.
34. Hirayama F, Lee AH, Binns CW, Nishimura K, Taniguchi H. Association of impaired respiratory function with urinary incontinence. Respirology. 2009;14:753–6.
35. Santana PV, Cardenas LZ, de Albuquerque ALP, de Carvalho CRR, Caruso P. Diaphragmatic ultrasound findings correlate with dyspnea, exercise tolerance, health-related quality of life and lung function in patients with fibrotic interstitial lung disease. BMC Pulm Med. 2019;19:183.
36. Li T, Wu X-Z, Long D, Fu H, Guo S, Liu F. Ultrasonographic modeling of lung and diaphragm mechanics: clinical trial of a novel non-invasive method to evaluate pre-operative pulmonary function. PeerJ. 2024;12: e18677.
37 Jung J, Kim N. The correlation between diaphragm thickness, diaphragmatic excursion, and pulmonary function in patients with chronic stroke. JPTS. 2017;29:2176–9.
38. Gao Z, Zhao K, Dai M, et al. Comparative study of different methods of autonomous breathing training on regional pulmonary ventilation. CJRM. 2024;39(5):634–40.

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