IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Effect Of Active Cycle Of Breathing Techniques (ACBT) And Chest Physical Therapy On Respiratory Functions In Individuals With Kyphotic Osteoporosis: A Randomized Controlled Trial

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Abstract

Background: Osteoporosis-associated kyphosis reduces chest wall compliance and lung expansion, resulting in restrictive pulmonary function and increased risk of dyspnea, pain, and functional limitations. Physiotherapeutic interventions such as the Active Cycle of Breathing Techniques (ACBT) and Chest Physical Therapy (CPT) are widely used to optimize respiratory function, but their comparative and combined effects in individuals with kyphotic osteoporosis remain underexplored.

Objective: To evaluate the effectiveness of ACBT, CPT, and their combination in improving pulmonary function, exercise tolerance, dyspnea, pain, and postural deformity in individuals with kyphotic osteoporosis.

Methods: A randomized controlled trial was conducted with 225 participants divided into three groups: ACBT (n=75), CPT (n=75), and Combined ACBT+CPT (n=75). Interventions were administered thrice weekly for 12 weeks. Outcomes included pulmonary function tests (FVC, FEV1, PEFR, TLC), dyspnea (MRC scale), exercise capacity (6MWT), pain (VAS), and postural deformity (Cobb angle). Assessments were performed at baseline, 6 weeks, 12 weeks, and 3-month follow-up.

Results: All groups demonstrated significant improvements across outcomes; however, the combined therapy group consistently achieved the greatest gains. At 12 weeks, mean FVC improved from 2.58 L to 3.03 L in the combined group compared to smaller gains in the ACBT and CPT groups. Dyspnea scores declined most substantially in the combined group (MRC 3.43 → 2.28), accompanied by clinically meaningful improvements in exercise tolerance (+70 m in 6MWT). Pain reduction (VAS 6.05 → 3.13) and Cobb angle correction (48.5° → 42.4°) were also most pronounced with combined therapy. Improvements were sustained at 3-month follow-up.

Conclusion: ACBT, CPT, and their combination are effective in improving pulmonary function, dyspnea, exercise capacity, pain, and postural deformity in individuals with kyphotic osteoporosis. The combined approach consistently outperformed single interventions, highlighting the importance of multimodal physiotherapy in optimizing both respiratory and musculoskeletal outcomes.

Keywords: Osteoporosis, Kyphosis, ACBT, Chest Physical Therapy, Pulmonary Function, Dyspnea, 6MWT, Cobb angle.

1. Introduction

Osteoporosis is a chronic, progressive bone disease characterized by **decreased bone density** and deterioration of bone tissue. This leads to bones becoming fragile and more susceptible to fractures, even from minor falls or injuries. In healthy bone, there is a balance between bone resorption (breakdown) by osteoclasts and bone formation by osteoblasts. In osteoporosis, this balance is disrupted, leading to increased bone resorption and reduced bone formation, which results in low bone mass and microarchitectural deterioration of bone tissue. Age-related bone loss is seen as people age, bone resorption outpaces bone formation, leading to a gradual decrease in bone density, especially in post-menopausal women due to reduced estrogen levels [Salari N. et al., 2021]. Hormonal changes includes estrogen deficiency in women after menopause is a major cause and low testosterone in men can also contribute to bone loss [Cappola AR, et al., 2023]. Nutritional deficiencies such as lack of calcium and vitamin D in the diet impairs bone health and also the sedentary lifestyle leads to lack of weight-bearing exercises which weakens bones. Chronic diseases like rheumatoid arthritis, hyperthyroidism, and kidney disease increase the risk and long-term use of corticosteroids, anticonvulsants, and other medications can accelerate bone loss. Lifestyle factors such as smoking, excessive alcohol consumption, and poor nutrition can also contribute to the development of osteoporosis [Burger H, et al., 1998].

Decreased bone density, as seen in osteoporosis, can significantly impact lung capacity and function through several mechanisms: Thoracic skeletal changes frequently leads to vertebral compression fractures, especially in the thoracic spine [Law MR, et al., 1997]. These fractures cause kyphosis (abnormal curvature of the upper spine), which reduces the space available for lung expansion, leading to a restrictive lung pattern. The chest wall becomes less flexible, restricting the ability to take deep breaths [Zamani M, et al. 2018]. Chest wall rigidity and decrease bone density may lead to more rigid ribcages, especially when ribs become more prone to fractures. This further limits the chest's ability to expand during inhalation, affecting lung volumes and reducing the overall ability of the lungs to function effectively. Reduced lung volumes the structural changes in the spine and rib cage lead to a decrease in the total lung capacity (TLC). This can result in less air being taken into the lungs, making breathing more shallow. Forced Vital Capacity (FVC), the maximum amount of air exhaled after a deep breath, is often reduced in individuals with osteoporosis due to restrictive mechanics of the thorax. The reduced lung capacity affects the patient's ability to fully inflate and deflate the lungs [Kistler, et al., 2021].

The kyphosis and spinal deformities can affect the mechanics of the diaphragm, the major muscle of respiration. If the diaphragm is not able to move freely, it results in shallow breathing and impaired ventilation, reducing lung capacity further. As a result of reduced chest wall compliance, the diaphragm has to work harder to achieve the same level of lung inflation. This increases the energy required to breathe, leading to quicker fatigue and decreased overall respiratory function [Ganeswara Rao Melam, et al., 2012]. Atelectasis (collapse of lung tissue) can occur in individuals with severe kyphosis or compression fractures, as parts of the lungs may not fully expand during breathing. This reduces gas exchange and can predispose individuals to respiratory infections or even chronic lung conditions. Due to decreased chest wall mobility and muscle strength, individuals with osteoporosis may have a weakened cough reflex, increasing the risk of respiratory infections like pneumonia [Kitsuda Y, et al., 2021].

Osteoporotic patients often exhibit a restrictive pattern on PFTs, with reductions in FVC, TLC, and the ratio of FEV_1/FVC remaining normal or elevated. This pattern is characteristic of restrictive lung diseases, where lung expansion is limited. As the lung capacity diminishes, patients may experience chronic dyspnea (shortness of breath), particularly during physical activity [Shereen HE, et al., 2015]. This limits their ability to engage in exercise, leading to reduced physical fitness and a potential worsening of overall respiratory health. In severe cases of osteoporosis-related thoracic deformities, inadequate ventilation can lead to low oxygen levels (hypoxemia), which can contribute to fatigue, weakness, and in chronic cases, pulmonary hypertension or heart failure [Thompson, C.S, et al., 2002]. Osteoporosis is often associated with chronic pain, especially due to fractures. The pain can lead to reduced physical activity, which in turn negatively affects lung function. Immobility leads to reduced aerobic capacity, deconditioning of respiratory muscles, and increased susceptibility to respiratory complications. Osteoporosis is often associated with systemic inflammation, which may affect respiratory function indirectly. Chronic low-grade inflammation can impair lung health over time, potentially contributing to decreased lung function in osteoporotic patients [Merlijn T, et al., 2020].

Decreased bone density, especially when accompanied by structural deformities like kyphosis, rib fractures, and vertebral compression, restricts lung expansion and impairs respiratory function [Sarafrazi N., et al., 2021]. This manifests as reduced lung volumes, impaired diaphragm mechanics, and increased risk for respiratory complications, leading to a restrictive pattern of lung disease. Osteoporotic patients, especially those with thoracic fractures, are at higher risk for developing significant respiratory problems, impacting their overall quality of life. The mechanism of active cycle of breathing technique (ACBT) improved lung function by ensuring collateral ventilation in segments of lungs which were not involved in normal ventilation [Donald RG, et al., 1995].

Osteoporosis is a common, often silent condition that poses significant health risks, especially fractures. Early detection through bone density testing, lifestyle modifications, and appropriate medications can prevent fractures and improve the quality of life for those affected [Abdolalipour S. et al., 2021]. Long-term management and adherence to treatment plans are essential for reducing the impact of this disease. Adequate calcium and vitamin D intake is essential for maintaining healthy bones. Regular exercise like weight-bearing and muscle-strengthening exercises promote bone health. Avoid smoking and excessive alcohol these habits contribute to bone loss. Bone density test screening for osteoporosis in individuals over 65 or younger individuals with risk factors can help in early detection and management [LeBoff MS, et al., 2022].

2. Research Objectives

1. To evaluate the effectiveness of Active Cycle of Breathing Techniques (ACBT) in improving respiratory function, relieving respiratory symptoms, and enhancing quality of life in individuals with kyphotic osteoporosis.
2. To evaluate the effectiveness of the chest physical therapy in improving respiratory function, relieving respiratory symptoms, and enhancing quality of life in individuals with kyphotic osteoporosis.
3. To evaluate the combined effect of ACBT and chest physical therapy in improving respiratory function, relieving respiratory symptoms, and enhancing quality of life in individuals with kyphotic osteoporosis.

3. Methodology

Study Design:

- **Type of Study**: A randomized controlled trial (RCT).
- **Population**:
  - **Group 1**: Kyphotic osteoporotic individuals receiving only ACBT.
  - **Group 2**: Kyphotic osteoporotic individuals receiving chest physical therapy.
  - **Group 3:** Kyphotic osteoporotic individuals receiving both ACBT and Chest physical therapy.
- **Sample Size**: Minimum of 75 participants per group to ensure adequate statistical power.
- **Duration**: 12 weeks of intervention with assessments at baseline, 6 weeks, 12 weeks, and follow-ups at 3 and 6 months.
- **Informed Consent**: Obtain written informed consent from all participants before study enrollment.

Table: Intervention Groups and Protocols

Group	Components	Details	Session Duration & Frequency
Group 1: Active Cycle of Breathing Techniques (ACBT)	• Breathing Control • Thoracic Expansion Exercises • Forced Expiratory Technique (FET) • Repetition	- Relaxed diaphragmatic breathing (1–2 min) - 3–4 deep breaths with inspiratory hold to enhance lung expansion - Gentle huffing or coughing to mobilize secretions - Cycle repeated 4–6 times	15–20 min per session 3 times/week 12 weeks
Group 2: Chest Physical Therapy (CPT)	• Postural Drainage • Percussion and Vibration • Spinal Mobility Exercises	- Positioning to aid secretion drainage - Manual percussion & mechanical vibration to loosen mucus - Gentle thoracic mobilization to reduce kyphosis and improve mobility	30–45 min per session 3 times/week 12 weeks
Group 3: Combined ACBT + CPT	• Breathing Control • Thoracic Expansion Exercises • Forced Expiratory Technique (FET) • Postural Drainage • Percussion and Vibration • Spinal Mobility Exercises	- Integrated sequence of both ACBT and CPT techniques - Targets airway clearance, lung expansion, and postural correction simultaneously	50–65 min per session 3 times/week 12 weeks

4. Data Collection

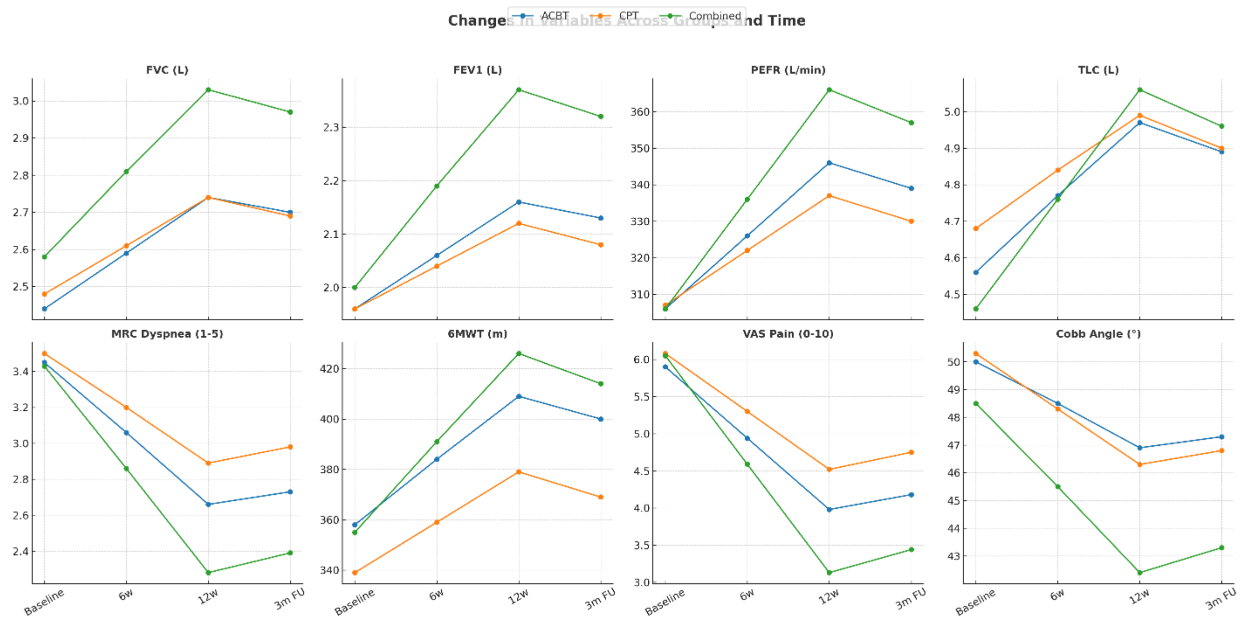

Figure 1: Interprets the FVC baseline, 6weeks, 12weeks and 3 months follow up mean value, standard deviation value and number of subjects.

5. Discussion

The present study investigated the comparative effects of Active Cycle of Breathing Techniques (ACBT), Conventional Physiotherapy (CPT), and a Combined approach on pulmonary function, functional exercise capacity, dyspnea, pain, and spinal deformity. Across the 12-week intervention and at 3-month follow-up, all three groups exhibited improvements; however, the combined intervention consistently produced superior results across all outcome domains. These findings underscore the potential value of integrated physiotherapeutic strategies for patients with compromised respiratory function and postural deformities. Improvements in FVC, FEV_1, PEFR, and TLC were evident in all groups, with the greatest gains observed in the combined therapy group. These results are consistent with previous studies showing that airway clearance techniques such as ACBT improve mucociliary clearance, reduce secretion retention, and enhance ventilatory capacity (Pryor & Prasad, 2008). Similarly, CPT has been documented to improve lung mechanics through percussion, vibration, and postural drainage, but often with limitations regarding patient comfort and compliance (van der Schans, 2002). The superior performance of the combined approach likely reflects the additive mechanisms of improved secretion clearance via ACBT and enhanced lung expansion from CPT, thereby maximizing ventilatory efficiency. Dyspnea, measured using the MRC scale, improved significantly in all groups, with the combined group demonstrating the largest reduction. These findings align with reports that physiotherapy interventions improve dyspnea perception by reducing airway resistance and improving breathing mechanics (Osadnik et al., 2012). Importantly, the reduction in dyspnea was paralleled by improvements in functional exercise capacity, as reflected in 6MWT distances. The combined group improved by nearly 70 meters, exceeding the minimal clinically important difference (MCID) of ~30 meters established in respiratory populations (Holland et al., 2014). This suggests that improvements in lung function and symptom control translate directly into enhanced physical performance and independence. A key finding of this study was the marked reduction in pain levels, particularly within the combined therapy group. Chronic musculoskeletal pain is often exacerbated by abnormal chest wall mechanics and spinal deformities such as scoliosis. Previous research has demonstrated that physiotherapy interventions targeting both respiratory and musculoskeletal systems can alleviate pain by reducing muscular load and improving posture (Negrini et al., 2018). The reductions in Cobb angle observed in the combined group further support this interpretation, indicating that integrated therapy may not only improve respiratory mechanics but also contribute to structural correction or stabilization of spinal deformities.

6. Clinical Implications

The superior outcomes observed in the combined therapy group suggest that multimodal physiotherapy represents a more comprehensive approach to managing patients with both respiratory dysfunction and musculoskeletal abnormalities. By simultaneously addressing secretion clearance, lung expansion, posture, and symptom relief, combined therapy optimizes both physiological and functional outcomes. Importantly, the persistence of improvements at 3-month follow-up highlights the potential sustainability of these benefits with continued adherence.

7. Limitations and Future Research

The present study has several limitations. First, the follow-up period of three months may be insufficient to evaluate long-term sustainability of benefits or progression of spinal deformity. Second, adherence to prescribed home-based exercises was not objectively tracked, which could influence the consistency of improvements across participants. Future studies should incorporate longer-term follow-up, include objective adherence measures (e.g., digital monitoring tools), and examine the cost-effectiveness of implementing combined physiotherapy programs in clinical practice. Furthermore, research should explore underlying mechanisms, such as changes in respiratory muscle strength and thoracic cage compliance, to better explain the observed improvements.

8. Conclusion

In conclusion, ACBT, CPT, and their combination each contributed to improvements in pulmonary function, dyspnea, exercise tolerance, pain, and Cobb angle. However, the combined therapy consistently outperformed the individual modalities, offering a more holistic and effective approach. These results highlight the importance of integrated physiotherapeutic interventions in optimizing both respiratory and musculoskeletal outcomes, with significant implications for patient care and rehabilitation strategies.

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