Original Article

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Physiotherapy Section

Effectiveness of Diaphragmatic Breathing Exercises on Cardiopulmonary Endurance and Perceived Exertion in Patients with Pulmonary Cancer: A Quasi-experimental Study

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ABSTRACT

Introduction: Lung cancer contributes to the worsening of a patient's respiratory condition by causing cardiopulmonary fatigue and increasing the effort to perform tasks. Supportive care includes exercises for the diaphragm like Diaphragmatic Breathing Exercises (DBE) to alleviate some of these symptoms.

Aim: The present study investigates the efficacy of DBE in improving cardiopulmonary endurance measured by maximal oxygen uptake (VO_2 max) and reducing Perceived Exertion (PE) by using Borg Scale in patients with stage II and III lung cancer.

Materials and Methods: This quasi-experimental study was conducted as a pre-post quasi-experimental design in collaboration with City Cancer Hospital, Vijayawada; Mahatma Gandhi Hospital, Visakhapatnam, Andhra Pradesh, India and other regional cancer centres for a period of one year from June 2023-May 2024, with a sample of 35 patients with lung cancer (stage II: n=16; stage III: n=19) from cancer hospitals in Vijayawada and Visakhapatnam. The patients underwent guided DBE training four times a day for five days a week. The study measured VO_2 max for cardiopulmonary endurance and the modified Borg Rating of Perceived Exertion (RPE) for exertion. The descriptive statistics were summarised for the demographic variables and the pre- and post-intervention changes within and between groups were assessed using Student's t-test with statistical significance set at p-value <0.05.

Results: The maximum number of patients belonged to the 45-49 years age group (54.3%) among the recruited patients, with 51.4% being males. A significant improvement was observed in VO_2 max for both stages. Stage II participants had VO_2 max of 31.69 mL/kg/min, which improved to 35.47 mL/kg/min (p-value <0.001). Stage III participants had VO_2 max of 31.67 mL/kg/min, which improved to 35.33 mL/kg/min (p-value <0.001). Furthermore, RPE showed significant changes as well; stage II participants from 3.63 to 2.50 and stage III participants from 4.26 to 2.37, both with p-value=0.001.

Conclusion: In patients with stage II and III lung cancer, DBE markedly improved cardiopulmonary function and reduced PE. It is a worthwhile investment and a physiologically beneficial intervention across various stages of the disease.

Keywords: Cardiopulmonary endurance, Fatigue, Modified Borg rating of perceived exertion, Lung cancer

INTRODUCTION

Lung cancer remains one of the most serious health challenges on a global scale, representing one of the leading causes of cancer-related deaths. The burden of lung cancer varies among different geographical regions mainly because of risk factors such as environmental pollution, smoking, and even dietary habits [1]. Approximately, over two million lung cancer patients are diagnosed each year, with nearly 85% of them having non small cell lung cancer. However, the pathological spectrum of lung cancer in Southeast Asia appears to be following the global trends of increasing incidence of adenocarcinoma as compared to squamous cell carcinoma [2]. Many patients experience severe respiratory symptoms, decreased exercise capability, and fatigue as the disease advances to stages II and III [3-5]. Cancer-related fatigue is often characterised as a persistent subjective sense of tiredness which is strictly not related to recent activity and is neither relieved by rest. Also, it presents during the entire course of the disease, resulting in the impairment of both day-to-day living and overall quality of life [4]. Physical exercises and activities are non pharmacological interventions that have been shown to improve fatigue, quality of life, cardiorespiratory fitness, pulmonary function, muscle mass and strength, and psychological status in patients with lung cancer [3]. Moreover, physical fitness levels, especially cardiorespiratory endurance and muscular strength, are demonstrated to be independent predictors of survival [4]. In addition to the disease burden itself, standard oncological treatments such as chemotherapy and radiotherapy contribute to systemic deconditioning. These treatments are known to exacerbate fatigue, impair oxygen transport mechanisms, induce inflammatory responses, and negatively impact pulmonary mechanics, thereby placing additional strain on cardiopulmonary function. Survivorship brings its own challenges, with chemotherapy and radiation therapy often elevating systemic fatigue and breathlessness and straining cardiopulmonary function [6]. Consequently, lung cancer survivors often face prolonged functional impairment even after completion of active treatment.

Patients with moderate-stage lung cancer often exhibit reduced oxygen uptake in terms of VO_2 max, impaired ventilation, and increased PE even during low-level physical activity [3,7]. VO_2 max is a well-established indicator of cardiopulmonary endurance and demonstrates the integrated efficiency of the respiratory, muscular, and cardiovascular systems [7]. A decline in VO_2 max is strongly associated with reduced functional capacity, early onset of fatigue, and limited tolerance to physical exertion. This contributes to physical inactivity, deconditioning, and decreased quality of life [8]. Increased PE is often assessed using the Borg

Rating of Perceived Exertion Scale which demonstrates the increased physiological and psychological burden experienced by the patients during activity [7].

Pulmonary rehabilitation has emerged as a critical non pharmacological strategy to counteract functional decline and improve symptom management in individuals with chronic respiratory conditions. DBE is a core component of pulmonary rehabilitation, which aims to optimise breathing mechanics by engaging the diaphragm, thus reducing accessory muscle usage and improving ventilation-perfusion efficiency [9,10]. DBE emphasises controlled, deep breathing that promotes diaphragmatic descent during inspiration, thereby reducing reliance on accessory muscles of respiration, which in turn alleviates the sensation of dyspnoea, improves respiratory muscle coordination, and promotes relaxation, making it a valuable intervention in populations with compromised pulmonary function. It enhances lung expansion, facilitates efficient gas exchange, and lowers the sensation of dyspnoea [11].

The therapeutic impact of DBE has been widely studied in Chronic Obstructive Lung Disorder (COPD) [12] and bronchial asthma [13], wherein DBE has demonstrated improvements in ventilatory efficiency, exercise tolerance, and symptom perception; its effect in stage-wise lung cancer rehabilitation remains underexplored. Therefore, the present study investigates the efficacy of DBE in improving cardiopulmonary endurance measured by VO_2 max and reducing PE by using Borg Scale in patients with stage II and III lung cancer.

MATERIALS AND METHODS

The present quasi-experimental pre-post study, in collaboration with City Cancer Hospital, Vijayawada; Mahatma Gandhi Hospital, Visakhapatnam, Andhra Pradesh, India and other regional cancer centres for a period of one year from June 2023-May 2024, a part of a large research project, was approved by the Institutional Ethics committee with reference number EC/2023-24/031, which confirmed compliance with the Helsinki Declaration. The study was conducted in collaboration with City Cancer Hospital, Vijayawada; Mahatma Gandhi Hospital, Visakhapatnam; and other regional cancer centres for a period of one year from June 2023-May 2024.

Sample size calculation: A total of 35 participants were recruited through purposive sampling including stage II (n=16) and stage III (n=19). The sample size estimation was based on Cohen's formula for 80% power at $\alpha = 0.05$ (two-tailed) to detect a standardised pre-post mean difference of approximately d = 0.49 in the whole sample. Subgroup analyses are powered for a small effect size of 0.75 in stage II and 0.68 in stage III. The effect size was calculated from a pilot study evaluating exercise tolerance in cancer rehabilitation.

Inclusion criteria: The patients between 45-70 years diagnosed with stage II or III lung cancer as per Eastern Cooperative Oncology Group (ECOG) performance scale [14], receiving chemotherapy but medically stable, able to ambulate independently with stable vitals at baseline, and able to comprehend instructions were included.

Exclusion criteria: Those diagnosed with or having a history of asthma or COPD, evidence of metastatic lung disease, thoracic deformities (kyphosis, scoliosis), inability to perform breathing exercises, and significant co-morbidities were excluded.

Study Procedure

Participants were taught diaphragmatic breathing using a standardised protocol which included a duration of 5-15 minutes per session, four sessions/day, five days/week, for eight weeks [15,16]. Supervision was provided during the initial sessions, followed by telephonic follow-ups and logs to ensure compliance. The cardiopulmonary endurance was estimated by VO_2 max (mL/kg/min) using the Six-Minute Walk Test (6MWT) protocol adapted for cancer patients [17] and PE by using the modified Borg rating of PE scale (mBorg) [18] at baseline (pre-test) and at 8-weeks (post-test). The mBorg is a vertical numeric scale, ranging from 0 "no perceived exertion/breathlessness" to 10 "maximal exertion/breathlessness" [18].

STATISTICAL ANALYSIS

Data were analysed using Statistical Package for the Social Sciences (SPSS) version 25.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics summarised demographic variables. The pre- and post-intervention changes within and between groups were assessed using a Student's t-test and statistical significance was set at p-value <0.05.

RESULTS

A total of 35 patients were recruited in the study as per the inclusion criteria. The distribution of patients as per cancer stage, age, and gender is demonstrated in [Table/Fig-1].

Variables	Category	n (%)
Cancer stage	Stage II	16 (45.7%)
	Stage III	19 (54.3%)
Age-wise	45-49 years	19 (54.3%)
	50-54 years	3 (8.57%)
	55-59 years	7 (20%)
	60-64 years	4 (11.42%)
	65-70 years	2 (5.71%)
Gender	Male	18 (51.4%)
	Female	17 (48.6%)

[Table/Fig-1]: Distribution of patients as per demographic characteristics.

The cardiopulmonary endurance was estimated by VO_2 max (mL/kg/min) using 6MWT protocol adapted for cancer patients which showed a significant improvement in VO_2 max after the intervention in both stage II and III patients (p-value <0.001). The improvement in VO_2 max is demonstrated in [Table/Fig-2].

Groups	Time	Mean±SE	95% CI	t value	p-value
Stage II	Pre	31.69±0.71	30.25-33.13	33.03	<0.001
	Post	35.47±0.78	33.88-37.06		
Stage III	Pre	31.67±0.65	30.35-32.99	33.86	<0.001
	Post	35.33±0.72	33.87-36.78		

[Table/Fig-2]: Cardiopulmonary endurance estimated by VO_2 max (mL/kg/min) using 6MWT protocol in both stages II and III patients at baseline (pre-test) and at 8-weeks (post-test).
Student's t-test is used. CI=Confidence Interval; SE: Standard error

The PE was reported by using Borg scale which showed a significant reduction in mean scores post-intervention in both stages II and III patients (p-value=0.001). The improvement in PE is demonstrated in [Table/Fig-3].

Groups	Time	Mean±SE	95% CI	t value	p-value
Stage II	Pre	3.63±0.42	2.78 - 4.47	2.573	0.001
	Post	2.50±0.34	1.80 - 3.20		
Stage III	Pre	4.26±0.38	3.48 - 5.04	2.331	0.001
	Post	2.37±0.32	1.73 - 3.01		

[Table/Fig-3]: Perceived Exertion (PE) by using mBorg in both stages II and III patients at baseline (pre-test) and at 8-weeks (post-test).
Student's t-test is used; SE: Standard error

DISCUSSION

The present study demonstrated that DBE significantly improved cardiopulmonary endurance and reduced PE in both stage II and stage III lung cancer patients. These findings are of substantial clinical relevance given the progressive decline in pulmonary function and quality of life observed in cancer patients as their disease advances and as they undergo chemotherapy and radiation therapy.

The observed improvement in VO_2 max is in line with existing literature that highlights the benefits of pulmonary rehabilitation in oncology settings [19]. Ding Q et al., conducted a meta-analysis on patients with early-stage lung cancer and reported that breathing exercises have been proven to improve pulmonary function in those suffering from lung tumours while also reducing the incidence of pneumonia following surgery [20]. Mulhaeriah et al., conducted a quasi-experimental study and reported that those undergoing chemotherapy improved fatigue levels and exercise tolerance following a structured breathing exercise program [21]. Similarly, Michaels C reported significant improvements in exercise performance and dyspnoea relief in cancer patients using diaphragmatic breathing, suggesting that the mechanism of benefit may extend to stage II and stage III cancer patients with compromised lung function and endurance [22].

While much of the evidence on DBE stands from chronic respiratory conditions such as COPD, asthma, and interstitial lung diseases, the applicability to oncological populations is gaining traction [23]. In a systematic review and meta-analysis by Ren J et al., breathing exercises, including DBE and pursed-lip breathing, were shown to improve pulmonary function and physical endurance in patients with lung cancer [24]. The present study confirmed and extended this evidence by comparing the impact of DBE across different cancer stages.

Moreover, although stage III patients had higher baseline PE scores than stage II, both groups responded comparably well to DBE, with a post-intervention rate of PE. This suggests that even patients with more advanced disease can benefit purposefully from non pharmacological interventions when appropriately rendered to clinical stability. Also, physiologically, cancer patients often adopt shallow thoracic breathing due to pain, fatigue, or deconditioning [25] while DBE encourages diaphragmatic activation, which improves lung expansion and reduces reliance on accessory respiratory muscles [9]. By promoting deeper and slower breathing, DBE facilitates more uniform alveolar ventilation, thereby improving oxygenation efficiency and reducing respiratory rate [26]. Breathing retraining has been shown to repress sympathetic activity, thereby suppressing the subjective sensation of breathlessness and anxiety, which are common in oncology settings [26]. Also, an enhanced VO_2 max suggests improved mitochondrial oxygen utilisation, possibly due to reduced cardiopulmonary strain and more efficient delivery of oxygen to peripheral tissue [27].

The findings that both cancer stages benefited similarly may suggest that diaphragmatic breathing induces systemic physiological improvements that are not strictly limited by tumour stage, provided the patient is haemodynamically and functionally stable [9,28].

The diaphragmatic breathing is a low-cost, low-risk, and easily teachable intervention that require minimal equipment and can be practiced at home or in outpatient settings [9,29]. It offers a feasible adjunct to pharmacological and physical therapies in oncology rehabilitation [30]. Moreover, the non-invasive nature of DBE makes it particularly suitable for frail or elderly cancer patients, who may be unable to engage in higher-intensity physical therapies [31]. All these factors add to the practical implication of DBE supported by the findings of the present study.

Limitation(s)

The absence of a control group limits the extent of inference, even though the pre- post design with statistically significant changes adds weight to the conclusions. The study lacks assessment of the long-term adherence and benefits of DBE. Also, the use of estimated VO_2 max, rather than direct cardiopulmonary exercise testing, might lack actual aerobic capacity changes.

CONCLUSION(S)

The DBE significantly enhance cardiopulmonary endurance and reduce exertion perception in stage II and III lung cancer patients. Following the ease of accessibility and administration, DBE should be integrated into comprehensive pulmonary rehabilitation programs for cancer patients. Moreover, the study adds to the growing body of evidence supporting DBE as a non pharmacologic, and stage-independent intervention for improving cardiopulmonary fitness and reducing exertion in lung cancer patients. As healthcare systems seek cost-effective ways to optimise cancer care, DBE stands out as a practical, evidence- based tool that empowers patients to participate actively in their own rehabilitation. A study can be conducted in future to determine the improvement in the quality of life of lung cancer patients following the exercise protocol. The duration of the study can be expanded with the involvement of the control group.

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