

Case Series

Effectiveness of Inspiratory Muscle Training in CKD With Cardiogenic Pulmonary Edema: A Case Series

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ABSTRACT

Background: Patients with chronic kidney disease (CKD) frequently develop cardiogenic pulmonary edema and associated respiratory muscle weakness, reduced chest expansion, increased dyspnea and reduced quality of life. Inspiratory muscle training (IMT) may help improve respiratory mechanics, oxygenation and patient reported outcomes in this population.

Context and Purpose of Study: To examine the effectiveness of supervised IMT in CKD patients with cardiogenic pulmonary edema using chest expansion, mMRC dyspnea, and SpO₂.

Results: The study showed significant improvements in all measured outcomes following the intervention. The average mMRC dyspnea score was reduced from 3.60 ± 0.55 to 1.00 ± 0.00 ($p < 0.001$), while mean SpO₂ increased from $91.80 \pm 1.30\%$ to $98.00 \pm 1.00\%$ ($p = 0.001$). Chest expansion also improved in all participants, indicating enhanced respiratory function. Overall, these findings demonstrate meaningful enhancements in respiratory function and clinical status.

Conclusion: The study found that IMT helped reduce dyspnea and improve oxygenation and chest expansion in CKD patients with cardiogenic pulmonary edema.

KEY WORDS: dyspnea, chest expansion, Inspiratory Resistance Training, Chronic Renal Insufficiency, Cardiac Pulmonary Edema.

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INTRODUCTION

Chronic kidney disease (CKD) is defined as a sustained reduction in kidney function for no less than a three months, with a GFR below 60 mL/min/1.73 m² or evidence of kidney damage, regardless of its underlying cause [1]. Over the past three decades, the number of

people living with chronic kidney disease (CKD) around the world has increased considerably [2]. Early-stage chronic kidney disease typically presents without obvious symptoms. As the condition progresses over months or years, however, patients may begin to experience issues such as fatigue, swelling (edema),

confusion, nausea, vomiting, and a decreased appetite [3]. Globally, nearly 850 million people are affected by kidney disease, according to the International Society of Nephrology [4].

Pulmonary edema (CPE) is the accumulation of surplus fluid within the lung tissues and air sacs. This occurs when high filling pressures in the heart elevate pulmonary venous pressure, forcing fluid out of the capillaries and into the lungs [5]. Within the heart failure population failure and reduced ejection fraction, cardiogenic pulmonary edema is reported to occur in approximately 75%–85% of cases. Being male or older in age may increase the risk of developing this condition [6]. Current research shows that between 25% and 65% of patients affected by chronic kidney disease experience pulmonary edema. In more advanced stages of the disease, most cases are triggered by heart-related issues [7].

Inspiratory muscle training (IMT) is a rehab method aimed at boosting the strength of the muscles used for breathing. This is achieved by having the patient inhale through a device that creates a specific level of resistance, similar to weight training for the lungs [8]. Inspiratory muscle training (IMT) is a strength-based exercise for the muscles used in breathing, intended to increase their power and optimise respiratory efficiency [9]. Other advantages include increased breathing capacity and delayed muscle exhaustion. These improvements are particularly vital for ICU patients transitioning away from mechanical ventilation [10]. Combining IMT with diaphragmatic or pursed-lip breathing may support improvements in breathing function and symptom relief than using breathing exercises alone [11]. Diaphragmatic breathing is a breathing technique that emphasizes diaphragmatic recruitment and promotes a more efficient breathing pattern. By slowing breathing and increasing the amount of air per breath (tidal volume), this exercise significantly improves oxygen-exchange efficiency [12]. Research suggests that individuals with CKD may experience changes in diaphragm structure and function. These changes suggest that targeted breathing exercises may help strengthen the diaphragm and improve respiratory

muscle function [13].

Pursed-lip breathing extends exhalation and prevents small-airway collapse, which helps reduce shortness of breath in individuals with respiratory issues [14]. By extending the exhalation phase, pursed-lip breathing creates a small amount of positive pressure within the airways. In other respiratory conditions, this technique prevents airway collapse and could similarly assist CKD patients whose lung flexibility is compromised by fluid buildup [15].

This case series aimed to assess changes in chest expansion, dyspnea using the modified Medical Research Council (mMRC) scale, and peripheral oxygen saturation (SpO₂) after two weeks of supervised respiratory physiotherapy in patients with CKD and cardiogenic pulmonary edema.

METHODS

Study Design - Case series.

Sample and Setting- Patients were recruited from a tertiary care hospital in Mangalore, Karnataka, India, between June 15, 2025, and July 15, 2025. Five patients diagnosed with chronic kidney disease (CKD) constituted the case series. Adults diagnosed with CKD were eligible if they were medically stable and willing to take part in the study. All patients were admitted and were under medical management during the study period. We evaluated dyspnea, SpO₂, and chest expansion at baseline and after the intervention in all participants. Outcome measures including peripheral oxygen saturation (SpO₂), modified Medical Research Council (mMRC) dyspnea scale, and chest expansion were recorded on the first day of intervention and after two weeks. Patients were excluded if they had a recent myocardial infarction, heart failure, cardiac arrhythmia, lung cancer, or other condition that made chest physiotherapy unsuitable. All participants received chest physiotherapy once daily for two weeks. Participants received a supervised respiratory physiotherapy program once daily for two weeks. The intervention consisted of diaphragmatic breathing and pursed-lip breathing. Participants completed three sets of 10 diaphragmatic breathing repetitions, separated

by brief periods of rest between each set. Pursed-lip breathing was also performed for 10 repetitions per set for 3 sets. A physiotherapist supervised each treatment session, while SpO₂, vital signs, and patient symptoms were checked before, during, and after the intervention.

Outcome measures: The mMRC dyspnea score, SpO₂, and chest expansion were recorded prior to and following the treatment to determine its effectiveness.

(a) mMRC Dyspnea Scale- The Modified Medical Research Council (mMRC) scale tracks breathing difficulty limits daily functioning by identifying specific activities that trigger it. Ranging from Grade 0 (breathlessness only during intense exercise) to Grade 4 (too breathless to leave the house), this tool is valued for being quick to administer and highly correlated with other respiratory disability measures. It is designed to evaluate the functional impact of breathlessness on a patient's life rather than just the physical intensity of the symptom itself [16]. The tool showed good reliability, with an ICC value of 0.82, supporting its role in clinical evaluation and research in this population [17].

(b) Pulse Oximetry (SpO₂) - At sea level, most healthy people have an SpO₂ level between 96% and 100%. Those who live at higher altitudes may normally have slightly lower readings. Pulse oximeters are generally designed to measure oxygen saturation from 70% to 100%, with an accuracy of about 2%–4%. When the reading falls below 70%, interpret it carefully because it may not match the oxygen level measured by an arterial blood gas test [18].

(c) Chest Expansion- Chest expansion (CE) is the measurement of the difference in chest circumference between a complete inhalation and a complete exhalation [19]. The inch tape method measures chest expansion while the patient sits comfortably. This clinical assessment involves placing a measuring tape around three specific thoracic levels: the axilla (upper), the nipple line (middle), and the xiphoid process (lower). Healthy individuals typically show expansion of 4-7 cm, but this decreases in those with lung pathology, with

smaller measurements generally indicating greater disease severity [20]. In healthy adults, chest expansion is generally around 4–7 cm, although the measured range may differ depending on the individual's health status [21]. Standard chest expansion typically decreases with age, falling by roughly 50–60% between ages 15 and 75. Additionally, these measurements are generally about 20% greater in men than in women.

RESULTS

The statistical analysis was performed using SPSS version 23.0. Categorical variables were presented as frequency and percentage, while descriptive variables were expressed as mean and standard deviation. Paired sample t-tests were used to compare pre- and post-intervention data within groups. A p-value < 0.05 was considered statistically significant.

All five participants experienced varying degrees of changes in their lives across different domains, with some exhibiting more pronounced changes in the MMRC Dyspnea Scale related to breathlessness. Chest expansion improved in following two weeks of chest physiotherapy, all five patients were reassessed. Additionally, dyspnea decreased, and SpO₂ levels improved significantly.

The baseline mMRC dyspnea score was 3.60 ± 0.55 and decreased to 1.00 ± 0.00 after the intervention. The median score improved from 4.0 at baseline to 1.0 at follow-up. The mean reduction in mMRC score was 2.60, and the improvement was statistically significant (paired $t = 10.61$, $p < 0.001$), indicating a marked reduction in dyspnea severity after the intervention. This indicates that the improvement from baseline to follow-up was significant.

The baseline SpO₂ level was 91.80 ± 1.304 , which increased to 98.00 ± 1.000 at follow-up. The mean improvement of 6.2 indicates a marked increase. The improvement was statistically significant ($t = 7.75$, $p = 0.001$), well below 0.05.

At baseline, all participants (100%) showed a chest expansion measurement of 01:01:01. At follow-up, all participants (100%) demonstrated an improved measurement of 01:02:01.

Table 1: Showing pre- post comparison of mMrc.

		Mean	Std. Deviation	Mean difference	t value	p value
mMrc	Baseline	3.6	0.548	2.6	10.61	0.001*
	Follow -up	1	0			

Fig. 1: Representing mean pre- post values of mMrc

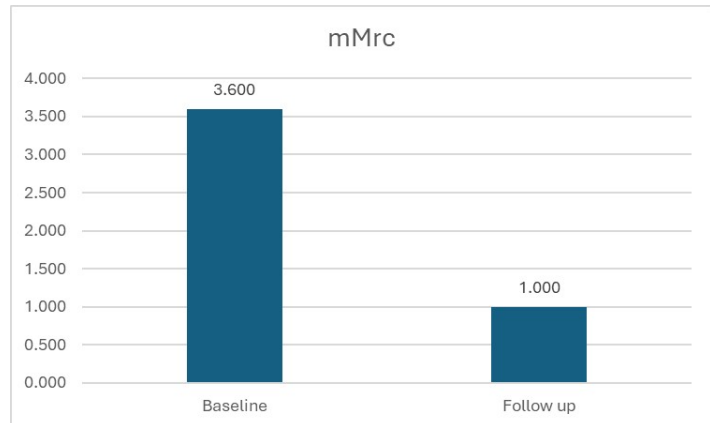


Table 2: Showing pre- post comparison of Spo2.

		Mean	Std. Deviation	Mean difference	t value	p value
Spo2	Baseline	91.8	1.304	6.2	7.75	0.001*
	Follow -up	98	1			

Fig. 2: Representing mean pre- post values of SpO₂

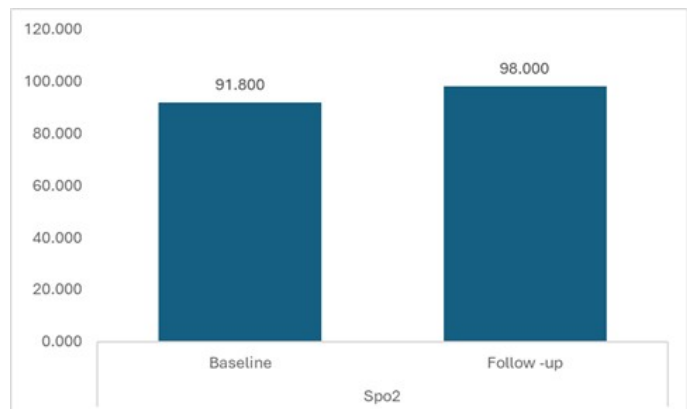


Table 3: Showing pre- post comparison of Chest Expansion in Axillary line.

		Mean	Std. Deviation	Mean Difference	t value	p value
Axillary Line	Baseline	76.8	5.22	1	-	p<0.001*
	Follow up	77.8	5.22			

Fig. 3: Representing mean pre- post values of Chest Expansion in Axillary Line.



Table 4: Showing pre- post comparison of Chest Expansion in Nipple line.

		Mean	Std. Deviation	Mean Difference	t value	p value
Nipple Line	Baseline	108.4	4.77	2	-	p<0.001*
	Follow up	110.4	4.77			

Fig. 4: Representing mean pre- post values of Chest Expansion in Nipple Line.

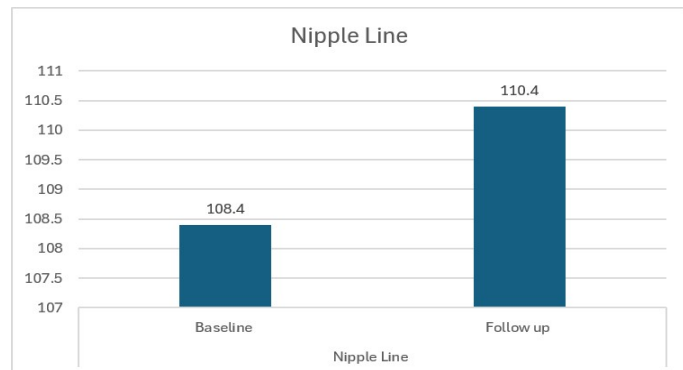
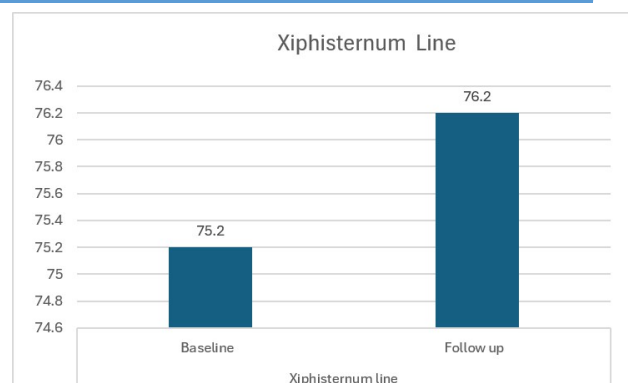


Table 5: Showing pre- post comparison of Chest Expansion in Xiphisternum line.

		Mean	Std. Deviation	Mean Difference	t value	p value
Xiphisternum line	Baseline	75.2	3.49	1	-	p<0.001*
	Follow up	76.2	3.49			

Fig. 5: Representing mean pre- post values of Chest Expansion in Xiphisternum Line.



DISCUSSION

In this case series, a two-week IMT program incorporating pursed-lip and diaphragmatic breathing improved SpO₂, mMRC dyspnea scores, and chest expansion among patients with CKD and cardiogenic pulmonary oedema. These observations align with findings from earlier studies involving CKD and other cardio-respiratory conditions.

Complementing this, a systematic review focusing on dyspnea and lung capacity outcomes in dialysis patients reported that IMT significantly improves inspiratory pressure and can modestly improve FVC, while reducing subjective dyspnea [22]. A systematic review by de Medeiros et al. (2017)

The literature has reported beneficial effects of IMT that can strengthen the inspiratory muscles and improve functional capacity and quality of life in people with CKD. The review highlighted that IMT could counteract the progressive respiratory muscle weakness commonly seen in CKD and enhance physical performance and daily functioning [23].

Moreover, recent studies (2018–2025) reported that IMT, even when applied for short durations or at high intensity, significantly increases maximal inspiratory pressure (MIP) and improves functional outcomes in CKD patients on hemodialysis, while combining it with breathing exercises may further optimise

oxygenation and dyspnea control. Additionally, IMT programs have been shown to be feasible in resource-limited settings. In a developing-country RCT, CKD patients receiving hemodialysis twice a week underwent 12 weeks of IMT at 50% MIP; the intervention improved MIP and quality-of-life scores, suggesting that IMT can be safely implemented even in constrained clinical settings [24]. These findings suggest that combining pursed-lip and diaphragmatic breathing with IMT may be a practical and beneficial approach for CKD individuals experiencing cardiac-related pulmonary edema in clinical practice.

Growing evidence suggests that, in addition to improving muscle strength and functional capacity, high-resistance inspiratory muscle training may also support vascular and endothelial health in people with CKD.²⁵ The authors propose that stronger inspiratory muscles may positively impact hemodynamics, reduce cardiovascular load, and thus be particularly relevant in CKD patients at risk for cardiovascular complications (including fluid overload and edema).

These findings align with recent studies reporting improvements in respiratory muscle strength, functional capacity, and quality of life following IMT among individuals with CKD. Overall, IMT may be a useful and safe addition to respiratory rehabilitation for CKD patients with respiratory difficulties. However, larger studies are needed to confirm these findings and determine the most suitable training approach.

CONCLUSION

A two-week Inspiratory Muscle Training intervention, combining pursed-lip and diaphragmatic breathing, significantly improved clinical outcomes in CKD patients with cardiogenic pulmonary oedema. Notably, these improvements suggest potential for reducing complications related to fluid overload and dyspnea in this population. This study highlights the importance of IMT in enhancing oxygenation, chest expansion, and functional capacity. Hence, it should be considered a valuable adjunctive therapy integrated management protocols for CKD

patients at risk of pulmonary edema. It underscores the significance of incorporating IMT into routine care to optimize respiratory function, alleviate dyspnea, improve SpO₂, and enhance overall patient well-being.

ABBREVIATIONS

CKD – Chronic kidney disease

CPE – Cardiogenic pulmonary edema

GFR – Glomerular filtration rate

IMT – Inspiratory muscle training

mMRC – modified Medical Research Council

SpO₂ – Peripheral oxygen saturation

AUTHORS CONTRIBUTION

Vishnu K Nair: Contributed to the conception of the study, guided throughout the manuscript preparation process and identifying the topic, performed critical revisions, and provided guidance in topic selection.

Priya S: Responsible for reviewing the study and providing critical intellectual input to ensure the accuracy and integrity of the work.

Stacy Santan Fernandes: Conceptualised and identified the research topic, performed data collection, collected study samples, conducted statistical analysis in collaboration with a statistician, and prepared the original manuscript.

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Conflicts of interest: None

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