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Assessing the Role of Inspiratory Muscle Training in Enhancing Respiratory Function among Adults with COPD

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DECLARATION

I, Gautambhai Kababhai Kalsariya declare that this dissertation has been composed by myself, that the work contained herein is entirely my own except where explicitly stated otherwise in the text, and that this work has not been submitted for any other degree or qualification, in whole or in part, except as specified.

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Date:07/01/2026

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ABSTRACT

Background: Chronic Obstructive Pulmonary Disease (COPD) is a progressive respiratory condition characterised by persistent airflow limitation, dyspnoea and reduced functional capacity. Inspiratory muscle dysfunction, particularly weakness of the diaphragm, plays a significant role in symptom burden and reduced quality of life among individuals with COPD. Inspiratory Muscle Training (IMT) has been proposed as a targeted, non-pharmacological intervention to strengthen inspiratory muscles and improve respiratory and functional outcomes; however, variability in training protocols and outcome measures has limited its consistent implementation within pulmonary rehabilitation.

Methods: A systematic literature review was conducted in accordance with PRISMA 2020 guidelines using the PEO (Population, Exposure, Outcome) framework. Electronic searches were performed across PubMed, ProQuest and PEDro databases to identify peer-reviewed quantitative studies published between 2015 and 2025. Studies involving adults diagnosed with COPD who received IMT as a standalone or adjunct intervention were included. Outcome measures included maximal inspiratory pressure (MIP), dyspnoea, lung function parameters and functional capacity assessed using the six-minute walk test (6MWT). Ten studies met the inclusion criteria and were critically appraised using Joanna Briggs Institute appraisal tools.

Results: Across the included studies, IMT consistently resulted in significant improvements in inspiratory muscle strength, as evidenced by increased MIP. Reductions in dyspnoea and clinically meaningful improvements in functional capacity, particularly 6MWT distance, were also observed. Greater benefits were reported when IMT was integrated with pulmonary rehabilitation or exercise-based interventions. Technologically enhanced and biofeedback-supported IMT demonstrated improved adherence and additional psychosocial benefits. Changes in spirometric lung function outcomes were variable.

Conclusion: The findings of this systematic review indicate that Inspiratory Muscle Training is an effective adjunctive intervention for improving inspiratory muscle strength, reducing dyspnoea and enhancing functional capacity in adults with COPD. Incorporating IMT into pulmonary rehabilitation programmes may optimise patient outcomes. Further high-quality research is required to establish standardised training protocols and to evaluate long-term clinical and psychosocial outcomes.

Keywords: Inspiratory Muscle Training (IMT), Respiratory Function, COPD, Chronic Obstructive Pulmonary Disease, Lung Function, Dyspnoea, Respiratory Muscles, 6-Minute Walk Distance, and Pulmonary Rehabilitation.

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ABBREVIATIONS

ABC Scale: Activities-Specific Balance Confidence Scale
BBS: Berg Balance Scale
CAT: COPD Assessment Test
CET: Cycle Ergometer Training
COPD: Chronic Obstructive Pulmonary Disease
CRQ: Chronic Respiratory Questionnaire
DALYs: Disability-Adjusted Life Years
EMG: Electromyography
ET: Endurance Training
FEV₁: Forced Expiratory Volume in One Second
FEV₁/FVC: Ratio of Forced Expiratory Volume to Forced Vital Capacity
FVC: Forced Vital Capacity
HAMA: Hamilton Anxiety Rating Scale
IMT: Inspiratory Muscle Training
IoT: Internet of Things
JBI: Joanna Briggs Institute
MDP: Multidimensional Dyspnoea Profile
MIP / PImax: Maximal Inspiratory Pressure
mMRC: Modified Medical Research Council Dyspnoea Scale
n: Sample Size
N: Total Number
NA / N/A: Not Applicable
NHS: National Health Service
NICE: National Institute for Health and Care Excellence
PEO: Population, Exposure, Outcome
PR: Pulmonary Rehabilitation
PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses
QoL: Quality of Life
RCT: Randomised Controlled Trial
SCM: Sternocleidomastoid Muscle
SD: Standard Deviation
SGRQ: St George's Respiratory Questionnaire
SLR: Systematic Literature Review
SMIP: Sustained Maximal Inspiratory Pressure
TIRE: Test of Incremental Respiratory Endurance

U: Unclear

UKRIO: UK Research Integrity Office

WHO: World Health Organization

6MWD: Six-Minute Walk Distance

6MWT: Six-Minute Walk Test

CHAPTER 1: INTRODUCTION AND BACKGROUND

1.1 Introduction

Chronic Obstructive Pulmonary Disease (COPD) is a progressive and debilitating respiratory condition characterised by persistent airflow limitation, chronic respiratory symptoms and reduced exercise tolerance (Agarwal et al., 2023). The World Health Organization (WHO) defines COPD as a common, preventable and treatable disease resulting from airway and/or alveolar abnormalities caused by prolonged exposure to noxious particles or gases, most commonly tobacco smoke and environmental pollution (World Health Organization, 2024). COPD represents a major public health challenge due to its high prevalence, increasing global burden and significant contribution to morbidity, mortality and healthcare utilisation (Boers et al., 2023).

A key but often under-addressed feature of COPD is respiratory muscle dysfunction, particularly weakness of the inspiratory muscles such as the diaphragm. Inspiratory muscle weakness contributes directly to dyspnoea, ventilatory inefficiency, reduced physical activity and diminished quality of life (Santana and Albuquerque, 2018). As COPD progresses, increased lung hyperinflation places mechanical disadvantage on the diaphragm, further exacerbating respiratory muscle fatigue and functional decline (Thomas et al., 2013).

Inspiratory Muscle Training (IMT) is a structured, non-pharmacological therapeutic intervention designed to strengthen the muscles involved in inspiration, primarily the diaphragm and accessory inspiratory muscles, by requiring individuals to breathe against an externally applied resistance (Langer et al., 2018). This resistance is typically delivered using threshold or resistive breathing devices and is prescribed as a percentage of an individual's maximal inspiratory pressure (MIP), allowing for progressive overload of the inspiratory muscles (Kowalski, Rodrigues and Zanini, 2025).

Inspiratory Muscle Training (IMT) has emerged as a targeted rehabilitative intervention designed to strengthen the inspiratory musculature through structured resistance-based breathing exercise (Ammous et al., 2023). IMT aims to improve inspiratory muscle strength, reduce breathlessness and enhance functional capacity (Ammous et al., 2023). This dissertation focuses on evaluating the effectiveness of IMT in adults with COPD through a systematic review of quantitative international studies, addressing an important and growing area within pulmonary rehabilitation research.

1.2 Background and Current Context

1.2.1 Definition and Pathophysiology of COPD

COPD is characterised by persistent airflow obstruction that is not fully reversible and is associated with abnormal inflammatory responses within the lungs (World Health

Organization, 2024). The disease encompasses two primary pathological processes: chronic bronchitis and emphysema (World Health Organization, 2024). Chronic bronchitis involves inflammation and narrowing of the bronchial airways, excessive mucus production and chronic cough, while emphysema is characterised by destruction of alveolar walls, resulting in reduced elastic recoil and impaired gas exchange (Global Initiative for Chronic Obstructive Lung Disease (GOLD), 2023).

At a physiological level, these structural changes lead to expiratory airflow limitation and air trapping, resulting in lung hyperinflation. Hyperinflation alters chest wall mechanics and flattens the diaphragm, reducing its force-generating capacity and efficiency (Saey et al., 2014). Consequently, individuals with COPD must expend a greater proportion of their total energy on breathing, increasing susceptibility to respiratory muscle fatigue.

Respiratory muscle dysfunction, particularly inspiratory muscle weakness, is now recognised as a central contributor to dyspnoea, exercise intolerance and disease progression (Poddighe et al., 2024). Maximal Inspiratory Pressure (P_Imax or MIP) is commonly used to assess inspiratory muscle strength, with studies consistently demonstrating reduced P_Imax values in individuals with COPD compared to healthy controls (Khalil et al., 2014). This dysfunction provides a strong physiological rationale for interventions specifically targeting the inspiratory muscles.

1.2.2 Global Prevalence and Burden of COPD

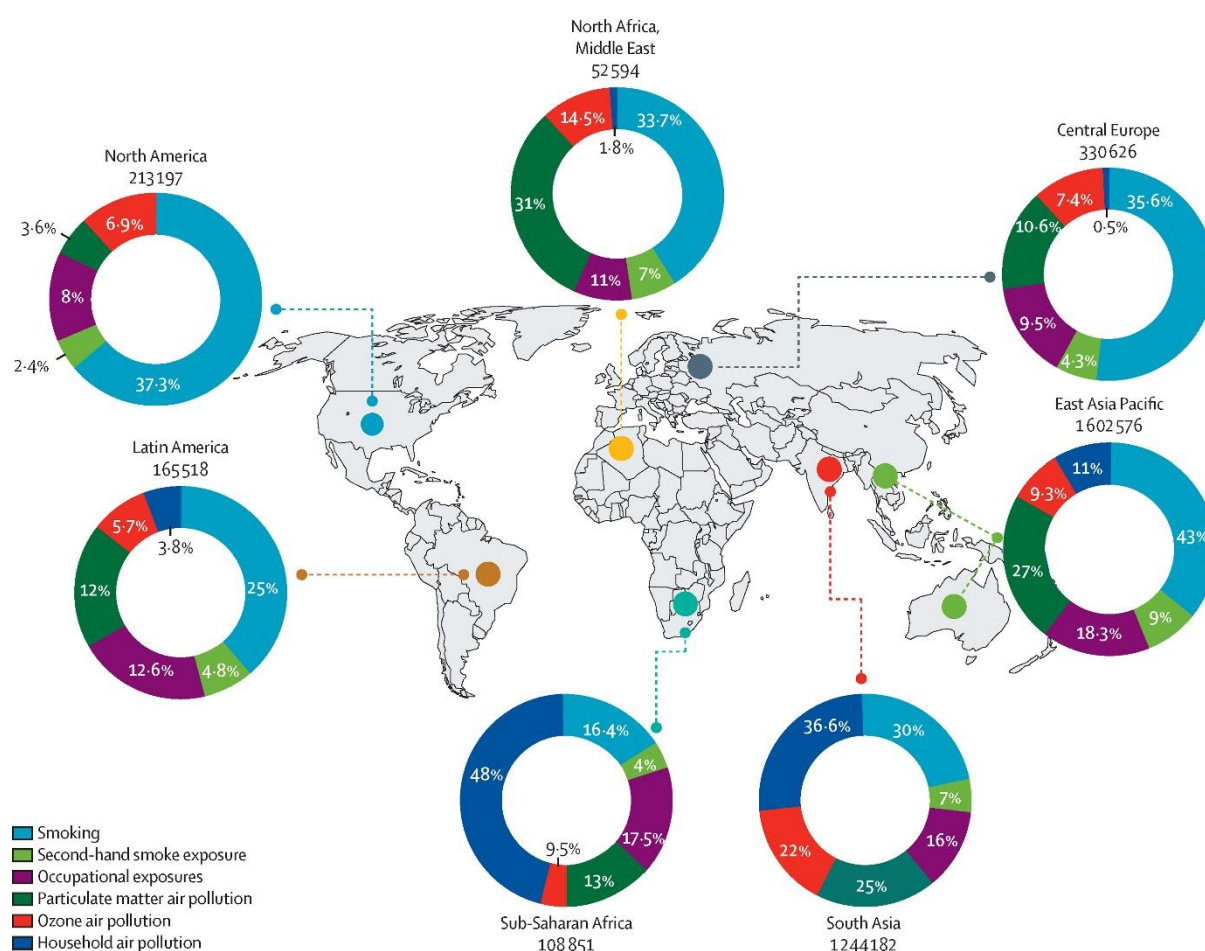
COPD represents one of the most significant non-communicable diseases worldwide. The Global Burden of Disease study estimates that approximately 391 million individuals globally are living with COPD, with prevalence continuing to rise due to ageing populations and persistent exposure to risk factors such as tobacco smoke and air pollution (Boers et al., 2023). Prevalence rates are particularly high among adults aged over 40 years, with global estimates suggesting that approximately one in ten adults in this age group has COPD (Halbert et al., 2006).

COPD is a leading cause of mortality. In 2019, the disease was responsible for an estimated 3.23 million deaths worldwide, ranking as the third leading cause of death globally (Li et al., 2022). In addition to premature mortality, COPD contributes substantially to disability-adjusted life years (DALYs), reflecting prolonged disability and reduced quality of life (Li et al., 2022).

The economic burden of COPD is also substantial. Direct costs include hospital admissions, long-term pharmacotherapy, oxygen therapy and frequent management of acute exacerbations. Indirect costs arise from loss of productivity, early retirement and caregiver burden (Pham et al., 2024). These impacts are particularly pronounced in low- and middle-

income countries, where exposure to biomass fuels and limited access to healthcare exacerbate disease severity and outcomes (Pham et al., 2024).

Figure 1: Global Burden of COPD



(Source: Montes et al., 2025)

1.2.3 COPD in the United Kingdom: Public Health Significance

COPD represents a major public health challenge within the United Kingdom. According to national estimates, approximately 1.17 million people in England have a diagnosed COPD, accounting for nearly 2% of the population (Kulakiewicz et al., 2021). However, true prevalence is likely higher due to underdiagnosis, particularly in early disease stages where symptoms may be misattributed to ageing or smoking-related breathlessness (Kulakiewicz et al., 2021).

COPD is responsible for over 30,000 deaths annually in the UK and remains one of the leading causes of emergency hospital admissions for respiratory disease (Health Education England, 2020). Acute exacerbations place significant strain on National Health Service (NHS) resources and are associated with accelerated lung function decline and increased mortality risk.

Importantly, COPD disproportionately affects individuals from socio-economically deprived backgrounds, reflecting higher smoking prevalence, occupational exposure to pollutants and reduced access to preventative healthcare (Pleasants et al., 2016). This inequitable disease distribution reinforces COPD as a priority public health concern requiring effective, accessible and evidence-based interventions (Pleasants et al., 2016).

1.2.4 Respiratory Muscle Dysfunction as a Therapeutic Target

Inspiratory muscle weakness is a critical contributor to symptom burden in COPD. Mechanical disadvantage of the diaphragm due to hyperinflation, combined with chronic loading and reduced muscle endurance, leads to decreased inspiratory force generation (Rossi et al., 2015). Reduced P_Imax is strongly associated with increased dyspnoea, lower exercise capacity and poorer health-related quality of life (Xiong et al., 2023).

Unlike irreversible structural lung damage, respiratory muscle dysfunction is potentially modifiable. Inspiratory muscles, like skeletal muscles, demonstrate adaptive responses to overload training, including increased strength and endurance (Gea et al., 2015). This adaptability supports the therapeutic rationale for IMT as a targeted intervention to address an otherwise under-treated component of COPD pathophysiology.

1.2.5 Inspiratory Muscle Training (IMT)

Inspiratory Muscle Training involves repeated breathing against resistance to strengthen the diaphragm and accessory inspiratory muscles (Ammous et al., 2023). IMT devices include threshold-loading devices, resistive breathing trainers and technologically advanced digital or biofeedback-enabled systems. Training intensity is typically prescribed as a percentage of P_Imax, allowing for progressive overload (Ammous et al., 2023).

Evidence indicates that IMT can improve inspiratory muscle strength, reduce dyspnoea and enhance exercise tolerance in individuals with COPD (Beaumont et al., 2015; Wu et al., 2017; Wang et al., 2017; Cirak et al., 2022). More recent studies incorporating digital monitoring and real-time feedback have demonstrated improved adherence and sustained functional benefits (Chen et al., 2024; Dosbaba et al., 2025).

1.2.6 IMT Within Pulmonary Rehabilitation

Pulmonary rehabilitation (PR) is a structured, multidisciplinary intervention that begins with comprehensive patient assessment and delivers individualised therapies such as exercise training, education and behaviour modification to enhance the physical and psychological wellbeing of individuals with chronic respiratory disease and support sustained health-promoting behaviours. (Shenoy and Paul, 2023). However, not all patients achieve optimal outcomes from PR alone, particularly those with marked inspiratory muscle weakness. Integrating IMT into PR programmes has been shown to provide additive benefits, including

greater improvements in dyspnoea and functional capacity (Wang et al., 2017; Cirak et al., 2022).

Despite growing evidence, IMT is not consistently implemented across PR services, partly due to variability in protocols and uncertainty regarding optimal training parameters. This gap between evidence and practice highlights the need for systematic evaluation of IMT effectiveness.

1.3 Rationale for the Research

This research was undertaken in response to increasing clinical and academic interest in Inspiratory Muscle Training (IMT) as an adjunctive intervention for individuals with Chronic Obstructive Pulmonary Disease (COPD). Respiratory muscle weakness is a recognised contributor to dyspnoea, reduced exercise tolerance and impaired quality of life in COPD, yet it is not consistently targeted within standard pulmonary rehabilitation programmes (Tonga and Oliver, 2023). Over the past decade, multiple quantitative studies have demonstrated that IMT can significantly improve inspiratory muscle strength, reduce breathlessness and enhance functional capacity in adults with COPD (Beaumont et al., 2015; Wang et al., 2017; Wu et al., 2017; Cirak et al., 2022).

Despite these positive findings, the existing evidence base is characterised by substantial heterogeneity in IMT modalities, training intensity, programme duration and outcome measures, limiting comparability across studies and hindering clinical implementation (Réginault et al., 2024). In addition, variability in study design and methodological quality reduces confidence in generalisability. A systematic review of quantitative studies is therefore warranted to synthesise current evidence, evaluate methodological robustness and clarify the role of IMT within pulmonary rehabilitation. This approach supports evidence-based practice and informs optimisation of IMT protocols in clinical settings.

1.4 Research Question

Does Inspiratory Muscle Training improve inspiratory muscle strength, functional capacity, respiratory function and related health outcomes among adults diagnosed with Chronic Obstructive Pulmonary Disease?

1.5 Research Aim

To evaluate the effectiveness of Inspiratory Muscle Training in improving respiratory and functional outcomes in adults with COPD.

1.6 Research Objectives

- To identify quantitative studies investigating IMT in adults with COPD.

- To evaluate the effects of IMT on inspiratory muscle strength, dyspnoea, functional capacity and respiratory outcomes.
- To synthesise international evidence and identify patterns across IMT interventions.
- To identify gaps and implications for clinical practice and future research.

1.7 Chapter Summary

This chapter introduced COPD as a significant global and national public health issue and highlighted inspiratory muscle dysfunction as a key contributor to symptom burden and functional decline. The role of respiratory muscle dysfunction, particularly inspiratory muscle weakness, was highlighted as a key contributor to dyspnoea, reduced functional capacity and impaired quality of life. Inspiratory Muscle Training (IMT) was presented as a targeted intervention with growing clinical relevance, alongside a rationale for further investigation due to variability within existing evidence. The research question, aim and objectives were defined to guide the study. The following chapter presents a critical review of existing literature relating to COPD, respiratory muscle dysfunction and IMT.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter presents a comprehensive and critical review of academic literature relating to Chronic Obstructive Pulmonary Disease (COPD), respiratory muscle dysfunction and the application of Inspiratory Muscle Training (IMT) as a therapeutic intervention. The purpose of this review is to establish the theoretical and empirical foundations underpinning IMT, critically evaluate the effectiveness of IMT interventions reported in quantitative studies, and identify methodological strengths, limitations and gaps within the current evidence base. The chapter synthesises peer-reviewed literature published from 2015 onwards, focusing on adult COPD populations and objective respiratory and functional outcomes. The findings of this chapter provide the rationale for the systematic review methodology adopted in Chapter 3 and contextualise the interpretation of results presented in subsequent chapters.

2.2 Literature Review

2.2.1 COPD Pathophysiology and Respiratory Muscle Dysfunction

COPD is characterised by persistent airflow limitation resulting from chronic airway inflammation, airway remodelling and alveolar destruction (World Health Organisation, 2024). These pathological processes lead to expiratory airflow obstruction, air trapping and lung hyperinflation. Hyperinflation is a defining feature of COPD and has profound implications for respiratory mechanics. As lung volumes increase, the diaphragm becomes shortened and flattened, resulting in a reduced length–tension relationship and diminished force-generating capacity (Rossi et al., 2015).

Respiratory muscle dysfunction in COPD is multifactorial. Mechanical disadvantage caused by hyperinflation is compounded by systemic inflammation, oxidative stress, hypoxaemia and altered protein metabolism, all of which contribute to structural and functional alterations within the diaphragm and accessory inspiratory muscles (Gea et al., 2015). Histological studies demonstrate fibre-type transformation, muscle atrophy and reduced contractile efficiency in the diaphragms of individuals with COPD (Gea et al., 2015). These changes result in reduced maximal inspiratory pressure (P_Imax), impaired endurance and early onset of respiratory muscle fatigue during physical activity.

Importantly, inspiratory muscle weakness is strongly associated with symptom severity. Lower P_Imax values correlate with increased dyspnoea, reduced exercise tolerance and poorer health-related quality of life (Iwakura et al., 2021). This relationship highlights respiratory muscle dysfunction as a clinically meaningful target for intervention.

2.2.2 Clinical and Public Health Burden of Respiratory Muscle Weakness

Dyspnoea is the primary symptom driving disability in COPD and is a major predictor of physical inactivity, hospitalisation and mortality (O'Donnell et al., 2019). Respiratory muscle weakness exacerbates dyspnoea by increasing the ventilatory cost of activity, thereby limiting participation in daily tasks. Reduced activity levels contribute to peripheral muscle deconditioning, metabolic dysfunction and disease progression, reinforcing a cycle of decline (Del Buono et al., 2019).

Pulmonary rehabilitation (PR) is a cornerstone of COPD management and improves exercise capacity and quality of life. However, PR outcomes are variable, and individuals with significant inspiratory muscle weakness often demonstrate attenuated responses to conventional exercise training alone (Xie et al., 2025). This has led to increased recognition that addressing respiratory muscle dysfunction may enhance PR effectiveness, particularly in patients with severe disease or persistent breathlessness (Xie et al., 2025).

From a public health perspective, interventions that reduce dyspnoea and improve functional independence have the potential to reduce hospital admissions, healthcare utilisation and economic burden (Henriques et al., 2024). As COPD prevalence continues to rise globally, targeted interventions such as IMT may contribute to more sustainable disease management strategies.

2.2.3 Theoretical Framework Underpinning Inspiratory Muscle Training

Inspiratory Muscle Training is grounded in established principles of skeletal muscle physiology. Respiratory muscles adapt to overload training through hypertrophy, increased neural drive and improved oxidative capacity, like limb muscles (Ren et al., 2025). IMT applies progressive resistance to inspiration, typically prescribed as a percentage of P_Imax, thereby stimulating strength and endurance adaptations (Álvarez-Herms et al., 2019).

Physiological adaptations associated with IMT include increased inspiratory muscle strength, delayed onset of respiratory muscle fatigue and reduced relative ventilatory demand during exercise. These adaptations improve ventilatory efficiency and reduce the sensation of breathlessness (Ren et al., 2025). Theoretical models suggest that reducing the work of breathing frees metabolic resources for locomotor muscles, thereby enhancing exercise tolerance (Ferguson et al., 2025).

This theoretical framework provides strong justification for IMT as a targeted intervention in COPD, particularly given the limited reversibility of airway obstruction and structural lung damage.

2.2.4 IMT Modalities and Technological Evolution

IMT modalities have evolved substantially over the past decade, reflecting technological advancements and improved understanding of respiratory muscle training principles.

Threshold IMT remains the most widely studied modality. It provides a fixed inspiratory load and is inexpensive and accessible. Studies using threshold devices consistently demonstrate improvements in P_Imax, although limitations include lack of continuous resistance and limited feedback (Beaumont et al., 2015).

Resistive IMT offers continuous resistance throughout inspiration. Wu et al. (2017) demonstrated superior improvements in inspiratory strength and dyspnoea compared with threshold IMT, suggesting enhanced muscle recruitment and training specificity.

Biofeedback-enhanced IMT, such as Test of Incremental Respiratory Endurance (TIRE), allows simultaneous training of strength and endurance with real-time visual feedback. Dosbaba et al. (2025) reported sustained improvements in P_Imax and inspiratory endurance over 24 weeks, highlighting the potential for long-term benefit.

Digital and IoT-supported IMT platforms represent a significant advancement. Chen et al. (2024) demonstrated that digitally monitored IMT improved adherence, respiratory function, dyspnoea and anxiety. Digital systems facilitate remote supervision and personalised progression, addressing common barriers to rehabilitation participation.

2.2.5 Effects of IMT on Inspiratory Muscle Strength

Inspiratory muscle strength, measured using P_Imax, is the most consistently improved outcome following IMT. Beaumont et al. (2015) demonstrated significant strength gains following threshold IMT, particularly in individuals with baseline weakness. This finding suggests that IMT may be most effective when targeted at patients with demonstrable inspiratory muscle impairment.

Wang et al. (2017) reported that combining IMT with aerobic exercise produced greater P_Imax improvements than exercise training alone, supporting the role of IMT as an adjunctive therapy. Wu et al. (2017) further demonstrated modality-specific differences, with resistive IMT producing superior strength gains compared with threshold loading.

Recent evidence indicates that biofeedback-based and digital IMT systems may enhance training effectiveness through improved adherence and progressive overload (Dosbaba et al., 2025; Chen et al., 2024). Collectively, these findings confirm IMT as an effective intervention for improving inspiratory muscle strength across COPD severity levels.

2.2.6 Effects of IMT on Functional Capacity

Functional capacity refers to an individual's ability to perform physical activities and daily tasks that require sustained physiological effort, reflecting the integrated function of the cardiovascular, respiratory and musculoskeletal systems (Arena et al., 2007).

Functional capacity commonly assessed using the Six-Minute Walk Test (6MWT), is a critical outcome in COPD rehabilitation. Improved walking distance reflects enhanced exercise tolerance and greater ability to perform daily activities (Dourado et al., 2025).

Wang et al. (2017) reported significant improvements in 6MWT distance following combined IMT and cycle ergometer training. Cirak et al. (2022) similarly demonstrated greater functional gains when IMT was integrated with manual therapy. Dellweg et al. (2017) observed improvements even among hypercapnic COPD patients, suggesting that IMT is effective in advanced disease.

Functional improvements are likely mediated by reduced ventilatory limitation, improved inspiratory efficiency and decreased dyspnoea during exertion. These outcomes are clinically meaningful, as functional capacity is closely linked to independence and prognosis in COPD (Shioya et al., 2018).

2.2.7 Effects of IMT on Dyspnoea and Symptom Burden

Dyspnoea reduction is a primary goal of COPD management. IMT has consistently demonstrated beneficial effects on breathlessness. Wu et al. (2017) reported significant reductions in dyspnoea scores following resistive IMT, while Chen et al. (2024) observed improvements using digitally supported IMT.

Reduced dyspnoea may result from improved inspiratory muscle efficiency and reduced central respiratory drive. Importantly, dyspnoea reduction facilitates increased physical activity, contributing to secondary benefits such as improved conditioning and psychological wellbeing (İrem Hüzmeli et al., 2024).

2.2.8 Quality of Life and Psychosocial Outcomes

Quality of life is a key outcome in COPD management. Several studies report significant improvements following IMT. Wang et al. (2017) observed improvements in CRQ domains, while Cirak et al. (2022) reported significant reductions in SGRQ scores.

Psychological outcomes remain under-investigated; however, emerging evidence suggests IMT may reduce anxiety related to breathlessness. Chen et al. (2024) demonstrated reduced anxiety scores following digital IMT, highlighting the potential psychosocial benefits of improved breathing control. Further research is needed to explore mental health outcomes systematically.

2.2.9 IMT Integration Within Pulmonary Rehabilitation

The integration of IMT within pulmonary rehabilitation appears to enhance overall rehabilitation outcomes, particularly in individuals with inspiratory muscle weakness. Evidence from Wang et al. (2017) and Tounsi et al. (2021) suggests that adding IMT to endurance-based training improves functional capacity beyond exercise training alone. Similarly, Cirak et al. (2022) demonstrated that combining IMT with manual therapy produced superior outcomes compared with IMT alone. These findings indicate that IMT may complement existing rehabilitation components; however, variation in implementation strategies highlights the need for clearer guidance on how IMT should be incorporated into standard PR programmes.

2.2.10 Methodological Limitations of Existing IMT Research

Across the included studies, methodological limitations may influence interpretation of findings. Small sample sizes, as reported by Beaumont et al. (2015) and Dellweg et al. (2017), reduce statistical power and generalisability. Blinding was rarely feasible, increasing the risk of performance bias. Additionally, variability in IMT intensity, duration and modality complicates comparison across studies. Although digital interventions such as those used by Chen et al. (2024) improved adherence monitoring, most studies relied on self-reported compliance, potentially overestimating intervention fidelity.

2.2.11 Identified Gaps in the Literature

Analysis of the ten quantitative studies included in this review reveals several important gaps within the existing IMT and COPD evidence base. Although all studies reported improvements in inspiratory muscle strength following IMT, there is no consensus regarding optimal training prescription. Across the studies, training intensity ranged from 30% to 60% of maximal inspiratory pressure, programme duration varied between six and 24 weeks, and both threshold and resistive IMT devices were used. This heterogeneity, evident in studies by Wang et al. (2017), Wu et al. (2017) and Dosbaba et al. (2025), limits direct comparison of outcomes and restricts the development of standardised clinical guidelines.

A further gap relates to limited long-term follow-up. Most studies assessed outcomes immediately post-intervention, with minimal evaluation of whether improvements in inspiratory muscle strength, dyspnoea or functional capacity were sustained beyond the training period. Even studies involving severe COPD populations, such as Dellweg et al. (2017), did not examine long-term disease progression, exacerbation frequency or hospital readmission rates. This restricts understanding of IMT's role in long-term COPD management.

Psychosocial outcomes were under-represented across the included studies. While Chen et al. (2024) evaluated anxiety and quality of life, most trials focused predominantly on physiological outcomes such as PImax and 6-minute walk distance. Given the high prevalence

of anxiety, depression and reduced self-efficacy in COPD, the limited assessment of psychological wellbeing represents a notable gap.

Additionally, two studies were conducted in single-centre settings with relatively small sample sizes, limiting generalisability. Studies such as Beaumont et al. (2015) and Dellweg et al. (2017) involved fewer than 35 participants, increasing the risk of selection bias and reducing statistical power. Few studies stratified outcomes according to COPD severity, comorbidities or baseline inspiratory muscle weakness, despite evidence that disease heterogeneity influences responsiveness to IMT.

Finally, direct comparisons between IMT modalities and evaluations of cost-effectiveness were scarce. Although Wu et al. (2017) compared resistive and threshold IMT and Dosbaba et al. (2025) assessed biofeedback-based IMT, economic evaluations and real-world implementation studies were largely absent. This limits translation of IMT into routine clinical practice, particularly within resource-constrained healthcare systems.

2.3 Chapter Summary

This chapter critically reviewed contemporary literature examining COPD pathophysiology, respiratory muscle dysfunction and Inspiratory Muscle Training. Evidence consistently demonstrates that IMT improves inspiratory muscle strength, functional capacity and dyspnoea in adults with COPD, particularly when integrated into pulmonary rehabilitation. However, heterogeneity in study design, intervention protocols and outcome measures limits comparability and clinical implementation. Significant gaps remain regarding standardisation, long-term effectiveness and psychosocial outcomes. These limitations justify the systematic review methodology presented in Chapter 3, which aims to synthesise quantitative evidence and clarify the role of IMT in COPD management.

CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter outlines the research methodology adopted for this systematic literature review, which examines the role of Inspiratory Muscle Training (IMT) in enhancing respiratory function among adults with Chronic Obstructive Pulmonary Disease (COPD). According to the World Health Organization (WHO), COPD is a common, preventable and treatable chronic lung condition characterised by persistent respiratory symptoms and airflow limitation resulting from airway and/or alveolar abnormalities caused by long-term exposure to harmful particles or gases (World Health Organization, 2024). COPD encompasses two primary pathological conditions chronic bronchitis and emphysema (World Health Organization, 2024). Chronic bronchitis involves chronic inflammation of the bronchial tubes leading to excessive mucus production and coughing, while emphysema is characterised by destruction of alveolar walls, reducing elastic recoil and impairing efficient gaseous exchange (World Health Organization, 2024). Together, these conditions significantly compromise respiratory function, contributing to dyspnoea, fatigue, and reduced exercise capacity.

COPD remains a significant global health concern, affecting more than 390 million people worldwide and ranking as the third leading cause of death (Boers et al., 2023). COPD remains a major public health burden, accounting for significant morbidity and mortality, particularly in the UK, where it affects an estimated 1.2 million people (Snell et al., 2016).

Inspiratory Muscle Training has emerged globally as an evidence-supported intervention aimed at improving inspiratory muscle strength, reducing dyspnoea and enhancing functional capacity in COPD (da Fontoura et al., 2025). Given the increasing use of IMT in pulmonary rehabilitation programmes worldwide, synthesising quantitative evidence is essential to determine its effectiveness across diverse clinical settings.

The methodology chapter details the steps taken to identify, select, appraise, and synthesise quantitative evidence relevant to the research question. It describes the use of a systematic literature review (SLR) approach, guided by the PEO framework (Population, Exposure, Outcome), which ensures a structured and replicable process. It also explains the search strategy, search terms, database selection, and inclusion and exclusion criteria. Additionally, ethical considerations and transparency measures, such as PRISMA reporting, are included to uphold scientific integrity. The chapter concludes with a summary linking this methodology to the subsequent results and analysis presented in Chapter 4.

3.2 Systematic Literature Review

A systematic literature review (SLR) is a comprehensive, transparent, and replicable process used to identify and synthesise all available evidence on a specific topic or intervention

(Carrera-Rivera et al., 2022). Unlike traditional or narrative reviews, SLRs follow a predefined protocol to minimise bias and improve the reliability of findings (Mengist et al., 2020).

The purpose of conducting an SLR in this context is to systematically evaluate the quantitative evidence exploring the impact of Inspiratory Muscle Training on respiratory function outcomes in adults with COPD (Qi et al., 2025). IMT has been increasingly utilised as a targeted intervention due to its capacity to improve inspiratory muscle strength, reduce exertional dyspnoea and augment exercise tolerance (Ramsook et al., 2017). However, variations in IMT protocols, intensities, durations and patient characteristics across global studies make it essential to synthesise evidence systematically to determine its overall effectiveness (Lima et al., 2025).

SLRs are widely recognised as the highest level of evidence in evidence-based practice because they rely on rigorous study selection, critical appraisal, and transparent reporting (Shaheen et al., 2023). The process typically follows five stages: (1) defining a research question; (2) developing a protocol and search strategy; (3) identifying and screening relevant literature; (4) extracting and synthesising data; and (5) presenting findings systematically, often guided by the PRISMA framework (Randles and Finnegan, 2023).

For this review, the SLR method was selected to systematically collect quantitative data from peer-reviewed primary studies focusing on IMT in COPD (Beaumont et al., 2018). Quantitative studies, such as randomised controlled trials (RCTs) and quantitative observational study, were chosen because they provide objective, numerical outcomes such as MIP, FEV₁, FVC, dyspnoea scores, and 6MWD allowing for measurable assessment of IMT effectiveness (Torres-Castro et al., 2025). This structured methodology ensures reliability, validity, and reproducibility while contributing to evidence-based recommendations for clinical practice in pulmonary rehabilitation.

3.3 Search Strategy

A search strategy is a systematic plan that identifies relevant research studies across academic databases using specific search terms, Boolean operators, and inclusion filters (Bramer et al., 2018). The search strategy for this review was developed using the PEO framework (Population, Exposure, Outcome), which is appropriate for non-interventional or single-exposure research questions.

- Population (P): Adults (≥18 years) diagnosed with COPD.
- Exposure (E): Inspiratory Muscle Training interventions.
- Outcome (O): Changes in respiratory function measured through MIP, FEV₁, FVC, dyspnoea, or 6MWD.

The search was conducted in three databases PubMed, ProQuest, and PEDro selected for their coverage of biomedical, allied health, and rehabilitation research. Searches were limited to English-language studies published between 2015 and 2025 to ensure recent and relevant evidence. Boolean operators (“AND”, “OR”) were used to combine keywords and synonyms, improving sensitivity and specificity (Oermann et al., 2021). For instance, combining “Inspiratory Muscle Training” AND “COPD” ensured retrieval of targeted literature.

Manual reference checking (snowballing) was also conducted to identify additional relevant studies not captured in database searches. The process adhered to PRISMA 2020 guidelines for transparency and replicability (Page et al., 2021a).

3.4 Search Terms

Search terms are the building blocks of a robust search strategy, ensuring comprehensive retrieval of relevant studies (MacFarlane et al., 2022). A combination of controlled vocabulary (MeSH) and free-text terms was used to capture variations in terminology across databases. Using synonyms and truncations maximised search coverage and avoided the omission of relevant studies due to inconsistent indexing (DeMars and Perruso, 2022).

The search terms were structured using the PEO framework, as presented in Table 1.

Table 1: PEO Framework and Search Terms

Element	Description	Keywords and MeSH Terms
Population (P)	Adults with COPD	“Chronic Obstructive Pulmonary Disease”, “COPD”, “Chronic Obstructive Lung Disease”, “Pulmonary Disease, Chronic Obstructive” [MeSH],
Exposure (E)	Inspiratory Muscle Training (IMT)	“Inspiratory Muscle Training”, “Respiratory Muscle Training”, “IMT”, “Breathing Exercises”, “Exercise Therapy” [MeSH], “Pulmonary Rehabilitation”
Outcome (O)	Respiratory function indicators	“Respiratory Function Tests” [MeSH], “Lung Function”, “Maximal Inspiratory Pressure (MIP)”, “Forced Expiratory Volume (FEV ₁)”, “Forced Vital Capacity (FVC)”, “Dyspnoea”, “6-Minute Walk Distance (6MWD)”

Example Search Strings

PubMed:

("respiratory muscle training" OR "inspiratory muscle training" OR "breathing exercises" OR "respiratory therapy" OR IMT) AND

(COPD OR "chronic obstructive pulmonary disease" OR "pulmonary disease, chronic obstructive"[MeSH]) AND

("respiratory function" OR "lung function" OR FEV1 OR FVC OR dyspnea OR MIP OR PImax OR "pulmonary function tests"[MeSH]) OR "6MWD" OR "Six Minute Walk Test"

ProQuest:

("Inspiratory Muscle Training" OR "Respiratory Muscle Training" OR IMT)

AND ("Chronic Obstructive Pulmonary Disease" OR COPD)

AND ("Respiratory Function" OR FEV1 OR MIP OR Dyspnoea OR 6MWD)

PEDro:

"Inspiratory Muscle Training" AND "COPD"

3.5 Keywords

Keywords are concise descriptors that capture the main concepts of a research topic and enhance discoverability in electronic databases (Pottier et al., 2024). For this review, both MeSH terms and free-text keywords were used. Keywords were selected based on their relevance to COPD, IMT, and respiratory outcomes, ensuring sensitivity and specificity in retrieval.

The main keywords included: Inspiratory Muscle Training, Respiratory Function, COPD, Chronic Obstructive Pulmonary Disease, Lung Function, Dyspnoea, Respiratory Muscles, 6-Minute Walk Distance, and Pulmonary Rehabilitation. These terms were consistently applied across all three databases, with Boolean operators combining synonyms to ensure comprehensive coverage.

Careful keyword selection was critical to avoid missing eligible studies while limiting irrelevant hits. The process adhered to recommendations for keyword optimisation in systematic reviews (Booth et al., 2021).

3.6 Databases

Three databases were chosen: PubMed, ProQuest, and PEDro. Each was selected for its specific relevance and contribution to capturing the breadth of literature in respiratory rehabilitation.

PubMed offers extensive biomedical coverage, indexing over 35 million citations from MEDLINE and life science journals. Its use of MeSH terms supports precise, standardised searching for health-related interventions (National Library of Medicine, 2025).

ProQuest expands coverage across international allied health, clinical, and interdisciplinary research fields, capturing studies not indexed in PubMed (ProQuest, 2024).

PEDro (Physiotherapy Evidence Database) was selected for its focus on physiotherapy and exercise-based interventions, particularly IMT trials. PEDro's pre-appraised RCT database provides additional methodological quality assurance (Moseley et al., 2019).

3.7 Inclusion and Exclusion Criteria

Inclusion and exclusion criteria are essential to maintain focus, minimise bias, and ensure methodological rigour (McDonagh et al., 2013).

Inclusion Criteria

- Adults (≥ 18 years) with confirmed COPD diagnosis.
- Studies using IMT as a primary or adjunct intervention.
- Quantitative designs.
- Outcomes included at least one of: MIP, FEV₁, FVC, dyspnoea, or 6MWD.
- Studies conducted worldwide.
- Published between 2015–2025, peer-reviewed, and available in full text in English.

Exclusion Criteria

- Studies on respiratory diseases other than COPD. (e.g., asthma and/or bronchiectasis).
- Non-quantitative or qualitative studies.
- Paediatric populations, animal studies, case reports, conference abstracts, or grey literature.
- Non-English language or no full-text availability.
- Lacking ethical approval or missing IMT intervention details.

The inclusion of only quantitative designs was justified by the study's aim to assess physiological outcomes. Excluding grey literature and non-peer-reviewed work ensured reliability, while restricting to recent studies maintained clinical relevance. The criteria were reviewed independently by two researchers to enhance objectivity and reduce selection bias (Page et al., 2021b).

3.8 Search Results

The systematic search of the three selected databases PubMed, ProQuest, and PEDro identified a total of 4,465 records. The broad PubMed search, which used comprehensive MeSH terms related to inspiratory muscle training and COPD, generated 2350 articles.

The ProQuest search conducted using a PEO-structured search string, generated 1265 results, and the PEDro search, restricted to clinical physiotherapy trials involving respiratory muscle training in COPD between 2015 and 2025, identified 850 studies.

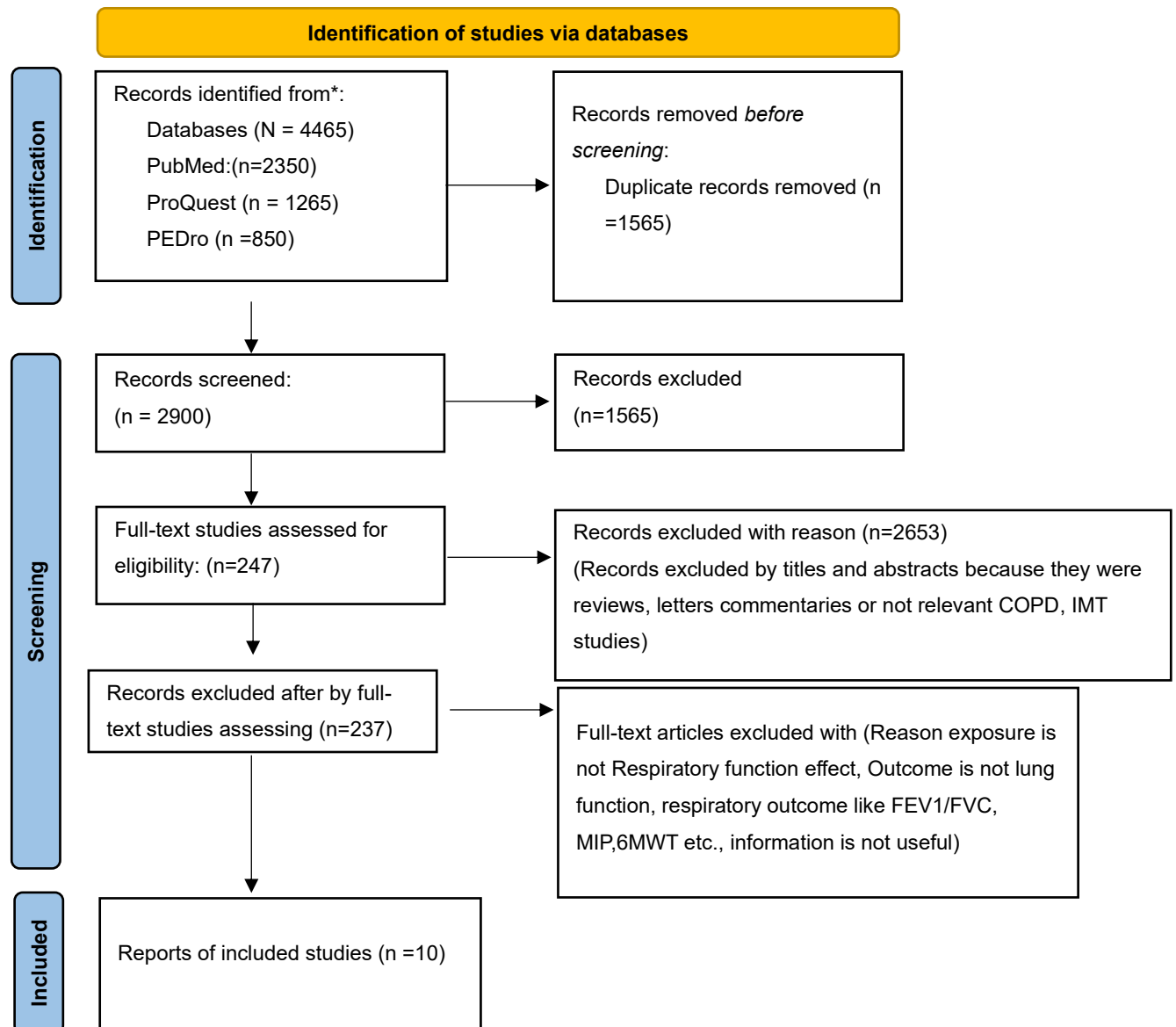
Combining all database searches resulted in an initial total of 4,465 records. Following the removal of 1,565 duplicates, 2,900 unique studies remained for title and abstract screening. During this stage, 2,365 studies were excluded because they did not meet the eligibility criteria. Reasons for exclusion included: study populations not involving COPD patients, absence of inspiratory muscle training interventions, studies focusing on unrelated respiratory therapies, qualitative or non-primary designs (such as reviews, commentaries), lack of relevant respiratory outcomes, non-English language publications, or unavailability of full-text articles.

A total of 247 full-text studies were retrieved and evaluated for eligibility. After detailed assessment, 237 studies were excluded for reasons including: lack of an IMT component; insufficient reporting of quantitative respiratory outcomes such as MIP, P_Imax or FEV₁; methodologies not aligned with quantitative research designs; interventions combining IMT with unrelated modalities; study populations not limited to COPD; or studies conducted in settings outside the scope of this review.

Ultimately, 10 quantitative primary studies met all inclusion and exclusion criteria and were included in the final review. These ten studies form the foundation of the evidence evaluated in Chapters 4 and 5, providing quantitative data on the impact of inspiratory muscle training on respiratory function, dyspnoea and functional capacity in individuals with COPD.

Figure 2: PRISMA Flow Chart (Page et al., 2021a)

PRISMA 2020 flow diagram for new systematic reviews which included searches of databases



3.9 Ethical Considerations

Ethical standards uphold research integrity and participant welfare (Resnik, 2020). This review involved secondary analysis of published data, eliminating the need for direct ethical approval. Nonetheless, all included studies were peer-reviewed and reported ethical clearance by relevant institutional review boards, including participant consent (Tripathy, 2013).

Ethical transparency was maintained by accurately citing all sources, avoiding plagiarism, and ensuring data integrity (Lalwani, 2025). The review adhered to the principles of honesty, objectivity, and respect for intellectual property, in line with the UK Research Integrity Office Code of Practice (UK Research Integrity Office, 2023). The inclusion of only ethically approved studies ensured participant protection in the original research. Furthermore, PRISMA reporting

enhanced methodological transparency, ensuring reproducibility and accountability (Page et al., 2021a).

3.10 Chapter Summary

This chapter presented a comprehensive and systematic approach to reviewing quantitative evidence on the effects of IMT in COPD populations. The methodology incorporated the PEO framework, robust database searching, and strict inclusion/exclusion criteria. A total of 4,465 studies were identified, with 10 meeting eligibility criteria. The PRISMA flow chart and study characteristics table detailed the selection and synthesis process.

By combining rigorous methodology with transparent reporting, this chapter provides a solid foundation for interpreting the evidence presented in Chapter 4. The next chapter will critically analyse the findings of these 10 quantitative studies, compare intervention outcomes, and discuss clinical implications for implementing IMT within pulmonary rehabilitation programmes across the United Kingdom.

CHAPTER 4: DATA EXTRACTION AND EVALUATION

4.1 Introduction

This chapter presents the processes of data extraction and critical appraisal undertaken for this systematic review, which aimed to assess the role of Inspiratory Muscle Training (IMT) in enhancing respiratory function among adults diagnosed with Chronic Obstructive Pulmonary Disease (COPD) (Blakey et al., 2017). Data extraction and appraisal form the methodological foundation of a systematic review, enabling the identification of key study characteristics, methodological strengths, and potential limitations that may influence the interpretation of findings (Büchter et al., 2020). The chapter begins by outlining the procedures used to extract relevant data from the included studies, followed by a discussion of the principles underpinning critical appraisal. The rationale for selecting appropriate appraisal tools is also presented. Subsequently, the chapter provides a detailed evaluation of the ten quantitative studies included in this review, appraised using the JBI Critical Appraisal Checklist for Randomised Controlled Trials and Quasi-Experimental Designs (Joanna Briggs Institute, 2020). The chapter concludes with a summary of the key insights gained through the appraisal process and a signpost to the next chapter, where the synthesised findings are discussed.

4.2 Data Extraction

Data extraction refers to the systematic and consistent process of retrieving key information from each included study to ensure accurate interpretation, comparison, and synthesis of findings (Afifi et al., 2023). A structured data extraction form was designed to guide this process, ensuring that relevant information was collected objectively and uniformly across all studies (Schmidt et al., 2023). The form captured details including study authors, year of publication, country, study aims, methodological design, COPD severity classification, sample size and characteristics, intervention type, IMT dosage parameters (intensity, duration, frequency), comparison groups, outcome measures such as maximal inspiratory pressure (PImax), forced expiratory volume (FEV1), dyspnoea indices, functional capacity measures (6MWD), and any secondary outcomes relating to quality of life or psychological variables. Extracted data were tabulated into a characteristics-of-studies table (see Appendix A), enabling cross-study comparisons and thematic synthesis. As all ten included studies were experimental or quasi-experimental in design, numerical data were available and extracted appropriately, supporting a robust quantitative synthesis of results presented in later chapters.

4.3 Introduction to Critical Appraisal and Paper Quality Assessment

Critical appraisal is the systematic evaluation of research evidence to determine its validity, reliability, and relevance for answering the review question. It enables reviewers to assess whether the methodology employed in each study is sufficiently rigorous to justify confidence in the reported findings (Almutairi et al., 2024). Critical appraisal is essential in systematic

reviews because studies often vary in methodological quality, sample size, intervention delivery, and outcome measurement, all of which influence the strength of the evidence base (Tod et al., 2021). Through appraisal, limitations such as selection bias, measurement bias, attrition, or inadequate control for confounding variables can be identified and acknowledged (Eldredge, 2024).

Appraisal also ensures transparency and reproducibility, allowing readers to understand how study quality influenced the review's interpretation. In quantitative research particularly in intervention studies evaluating elements such as randomisation, allocation concealment, blinding, treatment fidelity, adequacy of follow-up, validity of outcome measures, and appropriateness of statistical analyses is crucial (Yonis et al., 2025). Through systematic appraisal, this review ensures that the conclusions drawn regarding IMT effectiveness in COPD patients are grounded in high-quality evidence (Vázquez-Gandullo et al., 2022). The appraisal process therefore enhances the credibility and academic integrity of the systematic review.

4.4 Critical Appraisal Tools

Critical appraisal tools provide structured frameworks for systematically evaluating the quality and rigor of research studies (Tod et al., 2021). Selecting the most appropriate tool depends on the study design, as different designs present distinct methodological considerations. In this systematic review, the Joanna Briggs Institute (JBI) Critical Appraisal Checklists were selected as the primary tools for evaluating quantitative studies Designs (Joanna Briggs Institute, 2020). The JBI tools are widely recognised for their comprehensive, detailed, and context-sensitive approach to quality assessment, particularly for clinical and interventional studies Designs (Joanna Briggs Institute, 2020).

For randomised controlled trials, the JBI RCT Checklist evaluates domains such as randomisation procedures, allocation concealment, group similarity at baseline, blinding of participants and outcome assessors, treatment fidelity, reliability of outcome measures, appropriateness of statistical analysis, and management of withdrawals (JBI, 2020b). For quasi-experimental or non-randomised designs, the JBI Checklist for Quasi-Experimental Studies focuses on identifying confounding factors, clarity of cause effect relationships, comparability of groups, and the consistency of measurements (JBI, 2020a).

Given that all ten included studies employed quantitative, interventional, or observational designs, JBI was deemed the most suitable appraisal tool. Its structure ensured consistency in evaluating methodological strengths and weaknesses. Additionally, JBI supports transparent presentation of appraisal outcomes, as seen in Appendix B, facilitating critical comparison across studies (Joanna Briggs Institute, 2020). The use of JBI strengthens the

reliability of this review's conclusions by ensuring that only methodologically robust evidence informs the synthesis.

4.5 Evaluation of Quantitative Studies

4.5.1 Study Designs and Scope

All ten studies included in this systematic review adopted quantitative research designs, primarily randomised controlled trials (RCTs), with a smaller number of observational quantitative studies. RCTs are widely regarded as the most robust methodological approach for assessing clinical intervention effectiveness as they minimise bias through random allocation and controlled comparison (Hariton and Locascio, 2018). Studies such as Wang et al. (2017), Wu et al. (2017), Beaumont et al. (2015) and Chen et al. (2024) used randomised designs to evaluate the impact of Inspiratory Muscle Training (IMT) on a range of clinical outcomes in individuals diagnosed with COPD. Other studies, including Lee et al. (2021), adopted observational quantitative methods to explore physiological muscle activation during IMT.

Across the ten studies, the overarching aim was to determine the effectiveness of IMT in improving respiratory muscle strength, functional exercise capacity, dyspnoea, lung function parameters and health-related quality of life. While some studies investigated IMT as a standalone intervention (Wu et al., 2017; Dellweg et al., 2017), others evaluated its application alongside other rehabilitation modalities such as exercise training (Wang et al., 2017), manual therapy (Cirak et al., 2022) or digital home-based technologies (Chen et al., 2024). The diversity in IMT modalities including threshold loading IMT, resistive IMT, TIRE systems and IoT-based devices provided a broad evidence base. Sample sizes ranged from relatively small (Dellweg et al., 2017; n=29) to moderately sized trials (Wang et al., 2017; n=81), with intervention durations varying between three and 24 weeks. Together, these studies offer a comprehensive scope for evaluating IMT in COPD management.

4.5.2 Appraisal Criteria

All included studies were evaluated using the Joanna Briggs Institute (JBI) Critical Appraisal Checklists for Randomised Controlled Trials and Observational Studies. These tools assess several methodological domains including clarity of randomisation procedures, allocation concealment, group comparability at baseline, blinding of participants and outcome assessors, reliability and validity of outcome measures, treatment fidelity, appropriateness of statistical analyses and management of withdrawals (Joanna Briggs Institute, 2020).

Most RCTs displayed adequate randomisation procedures and provided baseline data demonstrating comparability across groups (e.g., Wang et al., 2017; Wu et al., 2017). However, blinding was rarely implemented due to the practical constraints of IMT, where

participants are typically aware of the intervention they are performing. Treatment fidelity was clearly described in several studies, particularly those involving structured IMT devices (Wu et al., 2017; Chen et al., 2024).

For observational studies such as Lee et al. (2021), the JBI Analytical Cross-Sectional Checklist was used to evaluate methodological clarity, sample representativeness, control for confounding factors and reliability of measurement tools (Joanna Briggs Institute, 2017). This ensured that although not experimental in design, the study was assessed according to appropriate quantitative appraisal standards.

4.5.3 Key Intervention Features and Main Outcomes

The ten studies employed different IMT modalities, training intensities and programme durations, though several common features were evident. Most studies utilised threshold loading IMT devices, which require patients to generate sufficient inspiratory pressure to overcome a set resistance (Beaumont et al., 2015; Wang et al., 2017). Others compared threshold IMT with resistive IMT (Wu et al., 2017), which provides continuous resistance rather than pressure-threshold loading. More recent studies explored advanced technologies such as TIRE-based IMT (Dosbaba et al., 2025) and IoT-based home training systems (Chen et al., 2024).

Intervention durations typically ranged between six and 12 weeks, although some extended to 24 weeks. Training intensity commonly involved 30–60% of maximal inspiratory pressure (P_Imax), allowing progressive loading of inspiratory muscles.

The principal outcome across studies was inspiratory muscle strength, typically measured via P_Imax. All studies reported significant improvements in P_Imax following IMT, confirming its effectiveness as a strength-training modality for respiratory muscles. Functional capacity, predominantly assessed using the Six-Minute Walk Test (6MWD), improved significantly in several trials, including those by Wang et al. (2017), Dellweg et al. (2017) and Cirak et al. (2022).

Dyspnoea was evaluated using tools such as the modified Medical Research Council (mMRC) scale and Borg scale. Improvements were frequently reported, with patients experiencing reduced breathlessness following IMT (Wu et al., 2017; Chen et al., 2024).

Lung function outcomes (such as FEV₁ or FEV₁/FVC) demonstrated mixed results. Although some studies identified modest improvements (Chen et al., 2024; Cirak et al., 2022), others reported no significant change, indicating that IMT may exert greater effects on functional rather than spirometry outcomes.

Quality of life measures, including SGRQ and CAT scores, improved significantly in several studies, particularly where IMT was integrated with comprehensive rehabilitation or digital-supported training (Wang et al., 2017; Chen et al., 2024).

Studies such as Lee et al. (2021) provided additional physiological insight, demonstrating increased activation of the diaphragm and accessory muscles during IMT, particularly at higher intensity loads.

4.5.4 Comparative Insights

Comparing findings across the ten studies highlighted several consistent trends. First, IMT led to improvements in P_Imax across all study designs and intervention modalities, confirming its effectiveness in strengthening the inspiratory musculature. The magnitude of improvement, however, varied between studies depending on device type, training intensity and participant characteristics. For instance, resistive IMT yielded superior improvements compared to threshold loading IMT in Wu et al.'s (2017) study, suggesting that continuous resistance may recruit respiratory muscles more effectively.

Second, greater improvements were observed when IMT was combined with other rehabilitation modalities. Studies combining IMT with exercise-based training (Wang et al., 2017) or manual therapy (Cirak et al., 2022) demonstrated enhanced outcomes compared with IMT alone. This indicates that multimodal rehabilitation approaches may provide synergistic benefits by targeting both respiratory muscle function and biomechanical factors such as thoracic mobility.

Third, digital platforms such as IoT-based IMT (Chen et al., 2024) and TIRE systems (Dosbaba et al., 2025) improved adherence, enabled remote monitoring and demonstrated additional benefits related to psychological wellbeing and reduced readmissions. This suggests that technology-enhanced IMT may have a meaningful role in supporting long-term self-management in COPD.

Fourth, studies involving more severe COPD populations, including hypercapnic patients post-weaning (Dellweg et al., 2017), reported substantial improvements in functional capacity and inspiratory strength, indicating that even individuals with advanced disease can benefit from IMT.

Overall, although intervention features varied considerably, the collective evidence supports IMT as a beneficial component of COPD rehabilitation.

4.5.5 Limitations of the Reviewed Studies

Despite the promising findings, several methodological limitations were noted across the reviewed studies. A common limitation was the lack of blinding for participants and personnel.

Given the nature of IMT, blinding is extremely difficult, which may introduce performance bias. Only a limited number of studies used sham training to address this issue (e.g., Dellweg et al., 2017).

Sample sizes in several studies were relatively small (Dellweg et al., 2017; Beaumont et al., 2015), reducing statistical power and increasing the risk of Type II errors. Small sample sizes also limit the generalisability of findings.

Another limitation was the heterogeneity of IMT devices, intervention durations and intensity protocols, which makes direct comparison across studies challenging. Additionally, adherence was inconsistently monitored, with some studies relying on patient self-report rather than objective tracking, potentially compromising intervention fidelity.

Most studies were conducted in single centres, which restricts external validity. Furthermore, long-term follow-up was limited, making it difficult to determine whether the benefits of IMT persist beyond the intervention period.

Finally, although several studies evaluated functional outcomes such as 6MWD or dyspnoea, fewer studies assessed long-term clinical endpoints such as exacerbation rates or hospital readmissions.

4.5.6 Strengths of the Reviewed Studies

The reviewed studies also possessed several strengths that enhanced the reliability of the evidence base. Most importantly, the majority employed RCT designs, which are considered the highest standard for clinical intervention research. Several studies included well-defined inclusion and exclusion criteria, ensuring that participants across trials were appropriately diagnosed with COPD and met relevant clinical thresholds.

The use of validated and reliable outcome measures, such as P_{lmax}, 6MWD, mMRC, CAT (COPD Assessment Test) and SGRQ (St George's Respiratory Questionnaire), improved internal validity and ensured consistency in evaluating IMT effects. Intervention protocols were generally well described, allowing for replication in clinical practice.

Some studies included innovative designs, such as incorporating sham interventions (Dellweg et al., 2017) or using digital monitoring infrastructure (Chen et al., 2024), which strengthened methodological robustness and adherence monitoring.

The diversity of IMT modalities and participant profiles including individuals with severe COPD, those undergoing pulmonary rehabilitation and technologically supported home-based training added breadth to the evidence base, supporting wider applicability of findings.

4.5.7 Conclusion

In conclusion, the quantitative studies reviewed in this section provide strong evidence supporting the effectiveness of IMT in improving inspiratory muscle strength, functional capacity and dyspnoea in individuals with COPD. Although limitations such as small sample sizes, lack of blinding and intervention variability were identified, the overall consistency of positive outcomes indicates that IMT is a valuable component of COPD rehabilitation. Comparative insights highlight that combining IMT with other interventions or incorporating digital technologies may enhance its effectiveness. The strengths and limitations identified in this section provide important context for interpreting the findings presented in the next chapter, which integrates results across studies to answer the research question.

CHAPTER 5: DATA ANALYSIS AND SYNTHESIS

5.1 Introduction

This chapter presents a comprehensive analysis and synthesis of the ten quantitative studies selected for this systematic review, each examining the role of Inspiratory Muscle Training (IMT) in enhancing respiratory and functional outcomes among individuals with Chronic Obstructive Pulmonary Disease (COPD). By applying a thematic analysis approach, this chapter explores the recurring patterns across the included studies and identifies the overarching themes that emerge from the data. These themes relate to improvements in inspiratory muscle strength, functional capacity, psychophysiological wellbeing and the influence of IMT intervention design.

The chapter begins by explaining the rationale for thematic analysis and the analytical framework adopted. It then provides a detailed overview of the characteristics of the included studies, highlighting variations in sample populations, intervention modalities and outcome measures. This is followed by a thematic synthesis of the findings, where each theme is explored through comparative interpretation across the studies. Finally, the chapter summarises the key findings and outlines how they inform the broader interpretations presented in Chapter 6.

5.2 Thematic Analysis

Thematic analysis is a qualitative method used to identify and interpret patterns of meaning within a dataset (Braun and Clarke, 2006). When applied within a systematic review, it is referred to as thematic synthesis, which enables researchers to integrate findings from multiple studies into coherent, higher-level interpretations. Although commonly used in qualitative research, thematic analysis is increasingly recognised as useful for synthesising quantitative evidence because many quantitative studies also contain narrative descriptions, contextual insights and explanatory findings that can be coded and organised into themes.

In the current review, thematic analysis was essential due to the heterogeneity in IMT devices, intervention durations, training intensities and outcome measures across the included studies. Coding of numerical outcomes (such as improvements in P_Imax or 6MWT) was complemented by coding of narrative elements describing mechanisms of improvement, participant response, therapy adherence and clinical implications. This approach enabled the identification of consistent patterns across studies and provided a deeper understanding of the broader impact of IMT on COPD management. Thematic analysis therefore served as a robust method to integrate multidimensional evidence from diverse quantitative sources.

5.3 Data Analysis Tool

Braun and Clarke's (2006) six-phase thematic framework guided the data synthesis process. The first phase involved immersion in the data through repeated reading of each study to identify both explicit outcomes and implicit meanings. In phase two, initial codes were generated to capture relevant features such as respiratory muscle strength improvement, functional gains, psychological outcomes and intervention design characteristics.

The third phase involved sorting these codes into potential themes by grouping related concepts. Phase four required reviewing and refining themes to ensure they accurately represented the dataset and were distinct from each other. In phase five, themes were clearly defined and named to reflect their conceptual meaning, while phase six involved producing the written synthesis that forms the core of this chapter.

This analytical approach allowed for both inductive theme generation and deductive refinement based on established theoretical principles in respiratory physiology and COPD rehabilitation. The method offered flexibility to interpret varied types of data while maintaining a structured process to ensure analytical rigour.

5.4 Characteristics of the Identified Studies

The ten included studies represent a diverse international body of evidence on the use of IMT in COPD. Two studies were conducted in China (Wang et al., 2017; Wu et al., 2017), and two were conducted in Taiwan (Lee et al., 2021; Chen et al., 2024). Other studies came from Tunisia (Tounsi et al., 2021), Turkey (Cirak et al., 2022), France (Beaumont et al., 2015), Germany (Dellweg et al., 2017), the Czech Republic (Dosbaba et al., 2025) and Brazil (de Farias et al., 2019).

Sample sizes ranged from 29 to 81 participants, and although demographic characteristics varied across studies, most focused on adults with moderate-to-severe COPD. Some studies examined participants with advanced disease, such as hypercapnic COPD patients in the study by Dellweg et al. (2017). Intervention duration varied widely, with training periods ranging from six to 24 weeks.

The IMT modalities also differed across studies. Threshold IMT was employed in several trials (Beaumont et al., 2015; Wang et al., 2017), while others used resistive devices (Wu et al., 2017), manually assisted therapy combined with IMT (Cirak et al., 2022), or advanced biofeedback-based systems (Dosbaba et al., 2025). Chen et al. (2024) implemented an IoT-supported IMT intervention allowing real-time monitoring and improved adherence.

Supervision levels ranged from fully supervised clinical sessions (Wang et al., 2017; Wu et al., 2017) to remotely monitored home-based training (Chen et al., 2024). Variations in baseline

disease severity also affected intervention responsiveness; for example, Beaumont et al. (2015) found limited improvement among participants without baseline inspiratory muscle weakness, whereas Dellweg et al. (2017) observed substantial improvements in more severe hypercapnic patients.

The study de Farias et al. (2019) did not provide outcome data but offered methodological insights into IMT prescription, expected outcomes and structured progression. This study contributed conceptually to theme development, particularly in relation to intervention design, expected strength gains and anticipated improvements in functional capacity.

5.5 Emerging Themes from Included Studies

During thematic synthesis, four themes were identified: (See Table-2)

1. Improvements in inspiratory muscle
2. Influence of intervention design on outcomes
3. Improvements in functional capacity
4. Psychophysiological and quality-of-life outcomes

Each theme is presented below with integrated comparative synthesis across all relevant studies.

Table 2: Themes and sub-themes identified from included studies

Themes	Sub-Themes	Key Findings	Articles for Extracted
Theme 1: Improvements in Inspiratory Muscle Strength	PI _{max} gains- Respiratory muscle endurance improvements	IMT consistently increased inspiratory muscle strength across COPD populations. Significant PI _{max} improvements were reported across most studies, with higher-intensity or resistive IMT producing superior adaptations. Endurance outcomes such as SMIP also improved in advanced modalities (e.g., TIRE), demonstrating enhanced sustained inspiratory effort. Strength gains were evident even in severe and hypercapnic COPD patients.	Wang et al. (2017); Wu et al. (2017); Beaumont et al. (2015); Cirak et al. (2022); Dellweg et al. (2017); Dosbaba et al. (2025); Chen et al. (2024); de Farias et al. (2019)

Theme 2: Influence of Intervention Design	Modality differences (threshold vs resistive IMT) Training intensity & progressive overload- Combined interventions (IMT + CET/manual therapy) Digital IMT delivery & adherence monitoring	The effectiveness of IMT was influenced by modality, intensity and delivery method. Resistive IMT often produced larger strength and dyspnoea improvements than threshold IMT. Higher training loads and progressive overload enhanced outcomes. Combined approaches (IMT + exercise/manual therapy) produced synergistic benefits. Digital and biofeedback-enhanced IMT improved adherence, training accuracy and patient engagement.	Wu et al. (2017); Lee et al. (2021); Wang et al. (2017); Cirak et al. (2022); Dosbaba et al. (2025); Chen et al. (2024); de Farias et al. (2019)
Theme 3: Improvements in Functional Capacity	Increased 6MWT distance- Reduced dyspnoea and exertional fatigue	IMT led to meaningful improvements in functional outcomes, including increased Six-Minute Walk Distance (6MWD) and reduced exertional dyspnoea. Combined interventions (IMT with aerobic training or manual therapy) produced greater gains than single-modality approaches. Improvements in ventilatory efficiency and reduced breathing workload contributed to enhanced endurance and activity tolerance.	Wang et al. (2017); Wu et al. (2017); Cirak et al. (2022); Dellweg et al. (2017); de Farias et al. (2019)
Theme 4: Psychophysiological & Quality-of-Life Outcomes	Reduced anxiety levels- Improved QoL (SGRQ, CAT, CRQ)	IMT demonstrated positive psychosocial benefits, including lowered anxiety, increased breathing confidence and improved health-related quality of life. Studies showed improvements across validated QoL scales such as SGRQ, CAT and CRQ. These changes reflect IMT's broader impact beyond physiological measures, supporting emotional wellbeing and daily functioning.	Chen et al. (2024); Wang et al. (2017); Cirak et al. (2022); Wu et al. (2017)

Theme 1: Improvements In Inspiratory Muscle Strength

Respiratory muscle strength improvements particularly in maximal inspiratory pressure (P_Imax) were the eight study's findings across the included studies. A wide range of IMT modalities demonstrated clear capacity to strengthen the inspiratory musculature, supporting

long-established evidence that respiratory muscles adapt positively to targeted loading. IMT combined with CET in Wang et al. (2017) resulted in significantly greater P_{lmax} improvements than CET alone, indicating that inspiratory strengthening plays a substantial role in enhancing respiratory function even within multimodal rehabilitation programmes. Wu et al. (2017) similarly found that both threshold and resistive IMT improved P_{lmax}, with resistive IMT outperforming threshold IMT due to its continuous loading characteristics that promote sustained muscle engagement.

Findings from Dosbaba et al. (2025) further reinforce the adaptability of respiratory muscles. Participants trained with the TIRE biofeedback system demonstrated significant improvements in P_{lmax} as well as sustained maximal inspiratory pressure (SMIP), indicating enhanced endurance capacity. These dual improvements demonstrate that IMT may influence both the phasic and tonic properties of the inspiratory muscles, allowing for both improved peak force and greater capacity to maintain repeated inspiratory efforts.

Dellweg et al. (2017) found meaningful P_{lmax} improvements in hypercapnic COPD patients, a group typically characterised by severe ventilatory limitation and high respiratory muscle load. Their results provide compelling evidence that IMT can benefit individuals even in the most advanced stages of COPD, if training is appropriately titrated. Beaumont et al. (2015) also demonstrated P_{lmax} gains, though improvements were smaller among those with preserved baseline strength, suggesting that IMT confers the greatest benefit when targeting documented weakness a finding coherent with general exercise science principles.

Other included studies demonstrated similar patterns. Cirak et al. (2022), who integrated manual therapy with IMT, observed significant P_{lmax} gains, suggesting that respiratory muscle strengthening may be complemented by interventions targeting thoracic mobility, allowing for more efficient diaphragm mechanics. Chen et al. (2024) reported strong P_{lmax} improvements following a digitally monitored IMT programme, highlighting the potential of technology-enhanced interventions to optimise adherence, ensure correct technique and maintain progressive loading.

Although de Farias et al. (2019) did not provide empirical results, the study anticipated substantial P_{lmax} improvements based on a structured IMT programme involving progressive loading between 40–60% of baseline P_{lmax}. These expected outcomes aligned closely with the empirical findings of other studies, reinforcing the physiological rationale behind IMT prescription.

Beyond maximal strength improvements, several studies highlighted meaningful gains in respiratory endurance. Dosbaba et al. (2025) found marked increases in SMIP, while Lee et al. (2021) demonstrated increased diaphragmatic and accessory muscle recruitment during

higher-intensity IMT sessions, confirming that progressive overload leads not only to hypertrophy but also improved neuromuscular coordination. Wang et al. (2017) also reported increases in inspiratory capacity, suggesting improved diaphragm mobility and reduced dynamic hyperinflation.

Collectively, these findings confirm that IMT significantly enhances inspiratory muscle function across COPD populations, with progressive, high-intensity or biofeedback-driven IMT producing the largest and most clinically meaningful improvements.

Theme 2: Influence Of Intervention Design

The second theme highlights the central role of intervention design in determining IMT effectiveness. Significant variation in outcomes across the reviewed studies was attributable to differences in modality, intensity, progression strategies, supervision and integration with complementary therapies.

Wu et al. (2017) showed that resistive IMT produced greater improvements in P_Imax, and dyspnoea compared with threshold IMT due to continuous resistance that provides a stronger training stimulus. Lee et al. (2021) demonstrated that higher-intensity IMT resulted in greater diaphragmatic activation, strengthening the rationale for progressive overload in IMT prescription.

Biofeedback-enhanced devices such as the TIRE system (Dosbaba et al., 2025) produced substantial gains due to real-time performance monitoring, encouraging optimal muscle recruitment and effort consistency. Similarly, digital IMT in Chen et al. (2024) improved adherence, training load accuracy and psychological engagement, demonstrating the potential of technology-enhanced rehabilitation to address barriers such as poor motivation or improper technique.

Combined therapies also played an important role. Wang et al. (2017) found that IMT combined with CET produced greater improvements than CET alone, while Cirak et al. (2022) demonstrated enhanced outcomes when IMT was integrated with manual therapy. These results suggest that IMT's effectiveness is amplified within multimodal rehabilitation programmes.

The study de Farias et al. (2019) highlighted methodological principles progressive loading, technique supervision, consistent session frequency that closely aligned with the most effective interventions across empirical studies, emphasising the importance of structured design in achieving optimal outcomes.

Theme 3: Improvements In Functional Capacity

Functional capacity improvements emerged as the third major theme, with five studies reporting enhanced exercise performance and reduced exertional breathlessness following IMT. The 6-minute walk test (6MWT), the most used measure of functional endurance, consistently demonstrated improvement across studies. Wang et al. (2017) found significantly greater increases in 6MWT distance among participants undergoing CET plus IMT compared to CET alone, highlighting how strengthened inspiratory muscles enhance whole-body oxygen utilisation and endurance. Similarly, Cirak et al. (2022) found substantial improvements in 6MWT following IMT combined with manual therapy, suggesting that improvements in breathing mechanics translate directly into improved functional outcomes.

Among hypercapnic COPD patients, Dellweg et al. (2017) also reported improvements in 6MWT performance. This is particularly relevant as hypercapnic individuals often face profound ventilatory limitations, and improvements observed in this group underscore IMT's potential applicability across severe COPD phenotypes. Likewise, Wu et al. (2017) demonstrated improved endurance capacity and reduced ventilatory limitation during exertion in IMT participants, providing physiological support for observed functional gains.

Dyspnoea reduction emerged as a consistent companion to functional improvement. Resistive IMT in Wu et al. (2017) resulted in greater dyspnoea reductions than threshold IMT. Chen et al. (2024) also reported reductions in mMRC dyspnoea scores following digitally enhanced IMT, while Wang et al. (2017) found reductions in dyspnoea during exercise. Beaumont et al. (2015) similarly observed dyspnoea improvements among participants with substantial respiratory impairment. These findings underscore the strong association between inspiratory muscle strength, ventilatory efficiency and perceived breathlessness.

De Farias et al. (2019) anticipated improvements in functional capacity based on the physiological rationale that IMT reduces the relative load on the inspiratory muscles during exertion. Improvements in 6MWT and dyspnoea across the included studies support these theoretical expectations, suggesting that IMT reduces respiratory muscle fatigue, delays dynamic hyperinflation and enhances breathing economy.

Moreover, psychological factors may mediate functional improvements. As respiratory efficiency increases, individuals often develop greater confidence in physical activity, reducing avoidance behaviours linked to dyspnoea-related fear. This may further contribute to improvements in 6MWT and daily mobility.

Altogether, these findings confirm that IMT leads to clinically significant improvements in exercise tolerance and dyspnoea across diverse COPD populations.

Theme 4: Psychophysiological And Quality-Of-Life Outcomes

IMT not only improves physiological outcomes but also enhances psychological wellbeing and quality of life (QoL). The ability to breathe more comfortably may reduce anxiety, fear of exertion and panic, which are prevalent among COPD patients. Chen et al. (2024) reported significant reductions in anxiety following IoT-supported IMT, illustrating the direct psychophysiological impact of improved respiratory control. Such findings align with the well-documented dyspnoea–anxiety cycle, where breathlessness triggers emotional distress and behavioural avoidance, further worsening respiratory function.

QoL improvements were observed via various validated measures. Wang et al. (2017) reported enhanced QoL in participants receiving IMT alongside CET. Cirak et al. (2022) noted significant improvements in SGRQ scores, and Chen et al. (2024) observed improved CAT scores following digital IMT. Wu et al. (2017) reported improvements across multiple CRQ domains, indicating enhanced emotional wellbeing, reduced fatigue and improved mastery.

The relationship between improved inspiratory muscle performance and QoL outcomes is likely multifactorial (Wang et al., 2017). Enhanced muscle function reduces dyspnoea, which in turn increases confidence and functional independence (Chen et al., 2024). As patients become more capable of engaging in daily activities, their social participation and emotional stability improve. Digital IMT interventions may further enhance these outcomes by increasing motivation, adherence and perceived support (Chen et al., 2024).

Although psychological and QoL outcomes were not uniformly measured in all included studies, the available evidence indicates that IMT is a holistic intervention capable of influencing physical, emotional and social domains.

Overall Synthesis of Emerging Themes

Collectively, these themes illustrate that IMT influences COPD health outcomes through interconnected physiological, functional and psychosocial pathways. Strength gains reduce the relative load on the respiratory system, facilitating improved breathing efficiency and endurance. These improvements translate into enhanced functional performance, reduced dyspnoea and improved psychological wellbeing. Intervention design profoundly moderates these effects, underscoring the importance of progressive loading, feedback mechanisms and integration with broader rehabilitation strategies. The convergence of findings across diverse countries and IMT modalities strengthens confidence in IMT as an evidence-based component of COPD management.

5.6 Chapter Summary

This chapter presented a detailed thematic analysis and synthesis of ten quantitative studies examining the impact of IMT on individuals with COPD. Four major themes emerged:

improvements in inspiratory muscle strength, enhancements in functional capacity, psychophysiological benefits and the influence of intervention design. The included studies consistently demonstrated that IMT significantly improves P_Imax, respiratory endurance, 6MWT performance and dyspnoea. Digital technologies, structured progression and combined therapy approach further enhanced IMT effectiveness. Although de Farias et al. (2019) provided protocol-only data, their methodological insights aligned strongly with the intervention principles underpinning successful IMT outcomes. Collectively, these findings highlight IMT as a valuable rehabilitation tool for COPD. The next chapter builds upon these insights by discussing clinical implications, limitations and recommendations for practice and future research.

CHAPTER 6: DISCUSSION

6.1 Introduction

This chapter presents a critical discussion of the findings from the systematic review carried out to examine the effectiveness of Inspiratory Muscle Training (IMT) in adults with Chronic Obstructive Pulmonary Disease (COPD). Building on the thematic synthesis outlined in Chapter Five, this chapter compares the review findings with existing literature, established theories and clinical guidelines. It offers a critical interpretation of how IMT influences respiratory muscle strength, functional capacity, psychological wellbeing and quality of life. In addition, it highlights unusual or unexpected findings and examines the methodological strengths and weaknesses that shaped the outcomes of the review. The chapter closes by summarising the implications of the findings as a basis for the conclusions and recommendations in Chapter Seven.

6.2 Discussion of Key Findings

The findings of this systematic review provide a strong body of evidence demonstrating the benefits of Inspiratory Muscle Training (IMT) across several domains relevant to COPD management. While the themes presented earlier summarise the principal outcomes, a deeper analysis reveals important clinical implications for the application of IMT in practice. This section expands further on these implications by critically interpreting how IMT outcomes translate into meaningful improvements for COPD populations, what these improvements suggest for clinical decision-making and how IMT programmes can be optimised for real-world respiratory rehabilitation.

Theme 1: Improvements in Inspiratory Muscle Strength

Improved inspiratory muscle strength has clear implications for clinical practice because weakened inspiratory muscles contribute directly to breathlessness, ventilatory inefficiency and reduced exercise tolerance in COPD. The consistent P_Imax improvements observed in Wang et al. (2017), Wu et al. (2017), Beaumont et al. (2015), Chen et al. (2024), Cirak et al. (2022) and Dosbaba et al. (2025) demonstrate that IMT effectively targets a physiological limitation central to COPD morbidity.

From a clinical perspective, the difference in outcomes related to baseline muscle weakness emphasises the importance of assessing inspiratory muscle function during patient evaluation. As shown by Dellweg et al. (2017), individuals with hypercapnia or marked weakness exhibited the greatest improvements, suggesting that IMT may be particularly beneficial for high-need groups. In contrast, patients with preserved baseline strength, as noted in Beaumont et al. (2015), may require more intensive or combined IMT to elicit meaningful improvements.

The variation in outcomes across IMT modalities also has important implications. The superior improvements achieved with resistive IMT (Wu et al., 2017) and TIRE-based biofeedback training (Dosbaba et al., 2025) suggest that devices offering continuous resistance or visual feedback may be more clinically effective than traditional threshold loading. Similarly, digital IMT programmes, such as those tested by Chen et al. (2024), may enhance adherence one of the main barriers to home-based rehabilitation.

The repeated observation across studies that progressive loading contributes to greater improvements supports a structured, monitored IMT prescription. The study design by de Farias et al. (2019), although not yet empirically tested, mirrors the most clinically effective programmes identified in this review and reinforces the idea that clinicians should tailor IMT intensity according to patient progression rather than using fixed or low resistance.

Overall, the improvements in inspiratory strength observed across the included studies underline IMT's potential role as a core element of COPD rehabilitation, particularly for patients presenting with respiratory muscle weakness or breathlessness that does not improve with traditional pulmonary rehabilitation alone.

Theme 2: Influence of Intervention Design

A major clinical implication emerging from this review is the importance of how IMT is delivered. Studies such as Wu et al. (2017) and Lee et al. (2021) highlight that intensity matters: higher loads and continuous resistance appear to produce greater physiological benefits. Programmes using progressive overload as in Wang et al. (2017) and de Farias et al. (2019) demonstrate that IMT is most effective when designed to increase difficulty as patients adapt.

The use of technology also appears promising. Digital monitoring (Chen et al., 2024) and biofeedback (Dosbaba et al., 2025) not only improved physiological outcomes but also increased adherence one of the biggest challenges in home-based rehabilitation. These findings suggest a future direction for IMT wherein remote monitoring plays a central role.

Furthermore, the enhanced outcomes observed in multi-modal programmes such as IMT + CET (Wang et al., 2017) or IMT + manual therapy (Cirak et al., 2022) suggest that clinicians should consider integrating IMT into broader rehabilitation frameworks rather than applying it in isolation.

In summary, the design and delivery of IMT significantly influence outcomes. Clinicians should prioritise progressive loading, sufficient intensity, biofeedback or digital support and integration into multimodal rehabilitation. These elements appear repeatedly in the studies that achieved the strongest results.

Theme 3: Improvements in Functional Capacity

The improvements in functional capacity reported across the studies have substantial implications for daily life functioning, independence and disease management in COPD. As demonstrated in Wang et al. (2017), Cirak et al. (2022), Dellweg et al. (2017) and Wu et al. (2017), increased 6MWT distance suggests enhanced exercise tolerance and improved ability to perform daily activities, such as walking, climbing stairs and carrying groceries.

Functionally, this is significant because reduced activity is strongly associated with disease progression in COPD. The reduction in dyspnoea observed alongside functional gains across multiple studies suggests that IMT helps break the cycle of breathlessness-induced inactivity. For example, Chen et al. (2024) and Wu et al. (2017) showed that dyspnoea relief directly contributed to improved exercise engagement.

A key clinical insight from these findings is that IMT may serve as a valuable adjunct to standard pulmonary rehabilitation (PR). Studies such as Wang et al. (2017) demonstrated that adding IMT to CET improved outcomes more than CET alone, suggesting that IMT enhances the benefits of existing PR programmes. Cirak et al. (2022) further demonstrated that integrating IMT with manual therapy improved functional outcomes, highlighting the synergy between respiratory training and therapies improving chest wall mechanics.

For individuals with severe COPD or hypercapnia, IMT appears particularly valuable. Dellweg et al. (2017) showed functional gains even in patients with severe respiratory limitation, indicating that IMT may provide benefits even when other rehabilitative strategies show limited effect. This finding broadens the potential patient population that could benefit from IMT beyond those typically included in conventional PR programmes.

From a clinical perspective, the improvements in functional capacity observed suggest that IMT should be considered for any COPD patient whose activity is limited by breathlessness, poor endurance, or ventilatory inefficiency. IMT may also be strategically applied pre-PR to strengthen patients sufficiently to engage in more demanding exercises.

Theme 4: Psychophysiological and Quality-of-Life Outcomes

The psychological and quality-of-life outcomes reported in Chen et al. (2024), Cirak et al. (2022), Wang et al. (2017) and Wu et al. (2017) highlight the broader relevance of IMT beyond physical function. Anxiety reduction following IMT (Chen et al., 2024) is clinically significant, as patients with COPD frequently experience anxiety because of unpredictable dyspnoea episodes.

Improved quality-of-life scores across multiple studies suggest that IMT contributes to emotional wellbeing, social engagement and perceived health control. Particularly important

is the observation from Wu et al. (2017) that mastery and emotional regulation improved alongside dyspnoea reductions. This demonstrates that IMT can empower patients to manage their symptoms more confidently, potentially reducing reliance on healthcare services.

Clinically, the psychosocial improvements indicate that IMT may be a valuable intervention for patients with both physical and emotional burdens from COPD. Digital IMT applications, such as those tested by Chen et al. (2024), may further support self-efficacy by providing structure, reassurance and continuous feedback important factors for long-term adherence.

6.3 Strengths and Limitations of the Review

This systematic review possesses several strengths. By focusing exclusively on IMT interventions in COPD, the review provides a concentrated synthesis of a highly relevant therapeutic area. The use of validated critical appraisal tools ensured that only methodologically sound studies were included. Thematic synthesis allowed for meaningful interpretation across diverse study designs, enabling identification of patterns and implications that may not be visible in single studies.

The inclusion of studies using different IMT modalities (e.g., threshold, resistive, digital, TIRE systems) strengthened the review by providing a multidimensional understanding of IMT's potential. Furthermore, the studies encompassed a wide range of COPD severities, including hypercapnic patients (Dellweg et al., 2017), offering insight into IMT's applicability across clinical subgroups.

However, limitations must be acknowledged. Study heterogeneity such as variation in training duration, intensity, supervision and outcome measures reduced the ability to make direct comparisons. Several studies had small sample sizes, limiting generalisability to wider populations. Only one study (Chen et al., 2024) examined psychological outcomes in depth, limiting understanding of IMT's broader psychosocial impact. Additionally, the inclusion of one protocol study (de Farias et al., 2019) meant that some thematic patterns incorporated anticipated rather than empirical results.

A further limitation is the short intervention period in two studies (Wu et al., 2017; Cirak et al., 2022), which restricts insight into long-term sustainability. None of the empirical studies provided evidence on whether IMT improvements persist beyond the training period. The restriction to English-language articles may also have introduced publication bias.

Despite these limitations, the review provides a robust and clinically relevant synthesis of IMT outcomes in COPD and offers meaningful insights for practice.

6.4 Chapter Summary

This chapter critically discussed the findings of the systematic review, comparing them with existing research and evaluating them in relation to theoretical and clinical frameworks. The analysis confirmed that IMT is an effective intervention for improving inspiratory muscle strength, functional capacity, dyspnoea, psychological wellbeing and overall quality of life among individuals with COPD. The discussion highlighted the importance of structured intervention design, progressive overload, digital enhancement and multimodal rehabilitation approaches. Strengths and limitations of the review were outlined, providing context for interpreting the findings. These insights lay the groundwork for the final conclusions and recommendations presented in Chapter 7.

CHAPTER 7: RECOMMENDATIONS AND CONCLUSION

7.1 Introduction

This chapter presents the recommendations and conclusion arising from the findings of this systematic review, which evaluated the effectiveness of Inspiratory Muscle Training (IMT) in improving respiratory, functional and psychosocial outcomes among adults with COPD. Building on the analysis and discussion in previous chapters, this chapter outlines the implications of the findings for clinical practice and highlights specific recommendations to support integration of IMT into COPD rehabilitation. Recommendations for future research are also provided to guide further investigation in this area. Finally, the chapter concludes by summarising the key findings, reinforcing the significance of the research topic and acknowledging the contribution of this review to existing knowledge.

7.2 Implications of Findings

The findings of this systematic review have several important implications for clinical practice, COPD management and respiratory rehabilitation. The consistent improvements in inspiratory muscle strength observed across all studies suggest that IMT should be considered a valuable therapeutic option for COPD patients with documented inspiratory muscle weakness or breathlessness that limits daily activities. Since studies such as Wang et al. (2017), Wu et al. (2017), Cirak et al. (2022) and Dosbaba et al. (2025) reported clear physiologic gains, these outcomes imply that IMT may help reduce the burden on the respiratory system, improve breathing efficiency and enhance patients' ability to participate in physical rehabilitation programmes.

Functional improvements, including increased 6MWT performance and reduced dyspnoea, indicate that IMT has the potential to enhance patients' independence and quality of daily functioning. The psychosocial benefits identified in Chen et al. (2024) and Wu et al. (2017) highlight IMT's role in supporting emotional wellbeing, suggesting that improved breath control may reduce anxiety and enhance confidence in symptom management.

The influence of intervention design suggests that clinicians need to carefully consider IMT structure, including intensity, progression and use of feedback technologies. Integrating IMT with existing pulmonary rehabilitation strategies, as demonstrated in Wang et al. (2017) and Cirak et al. (2022), may maximise therapeutic outcomes. Overall, the findings imply that IMT can be used as a targeted intervention to address multiple clinical needs within COPD care pathways.

7.3 Recommendations for Practice

Based on the findings of this systematic review, several recommendations can be made to facilitate effective implementation of IMT in clinical practice. First, clinicians should conduct

routine assessments of inspiratory muscle strength in COPD patients to identify individuals who may benefit most from IMT. Patients with documented weakness, such as those like the participants in Dellweg et al. (2017), are likely to experience substantial improvements.

Second, IMT should be delivered using progressive resistance tailored to everyone's baseline function, ensuring appropriate loading and physiological adaptation. Evidence from Wu et al. (2017), Dosbaba et al. (2025) and Chen et al. (2024) suggests that interventions with continuous resistance, biofeedback or digital monitoring achieve superior outcomes, implying that these modalities should be prioritised where resources permit.

Third, IMT should be integrated into existing pulmonary rehabilitation (PR) programmes. Studies such as Wang et al. (2017) demonstrated that IMT enhances the functional outcomes of CET, indicating that combined exercise approaches may be more effective than standalone interventions. Clinicians should therefore consider including IMT at the beginning of PR programmes to improve initial capacity and support participation in higher-intensity activities.

Fourth, practitioners should provide clear education and training to ensure adherence, particularly for home-based IMT programmes. Digital tools, like those in Chen et al. (2024), may enhance adherence and provide remote monitoring, making them valuable additions to clinical practice.

Lastly, clinicians should monitor psychological responses to IMT, as improvements in anxiety and confidence suggest potential benefits beyond respiratory function alone. This holistic approach may improve overall patient engagement and wellbeing.

7.4 Recommendations for Future Research

Although the existing studies provide strong evidence of IMT's benefits, several gaps remain that future research should address. First, there is a need for larger scale randomised controlled trials to verify the generalisability of findings across wider COPD populations, as many studies included relatively small sample sizes. Expanding participant diversity, including those with varying disease severities and comorbidities, would improve external validity.

Second, long-term follow-up studies are essential to evaluate the sustainability of IMT improvements. None of the empirical studies in this review assessed outcomes beyond the immediate post-intervention period, limiting understanding of whether benefits persist without continued training. Future research should therefore investigate optimal maintenance strategies to preserve gains in inspiratory strength and functional capacity.

Third, further exploration of digital and technology-enhanced IMT interventions is warranted. Studies such as Chen et al. (2024) and Dosbaba et al. (2025) show promising results, but research is needed to compare different digital platforms, assess cost-effectiveness and

determine impacts on long-term adherence. Investigating tele-rehabilitation models integrating IMT into home-based care may also be valuable.

Fourth, studies should examine the psychological and quality-of-life effects of IMT in greater detail. Outcomes in Wu et al. (2017), Cirak et al. (2022) and Chen et al. (2024) indicate psychosocial benefits, but more comprehensive assessments are needed to understand the mechanisms underlying these improvements.

Finally, future research should investigate optimal training parameters, including duration, intensity, frequency and progression. Although studies such as de Farias et al. (2019), Wu et al. (2017) and Lee et al. (2021) provide guidance. Standardising IMT prescribing guidelines would support clinicians and improve consistency in clinical practice.

7.5 Conclusion

This systematic review explored the effectiveness of Inspiratory Muscle Training (IMT) in improving respiratory, functional and psychosocial outcomes among individuals with COPD. The research topic centred on evaluating whether IMT enhances inspiratory muscle strength, functional capacity and quality of life. The findings from the ten included studies consistently demonstrated that IMT offers significant benefits across these domains.

The review addressed the primary research question: Does Inspiratory Muscle Training improve respiratory function and related outcomes among individuals with COPD? The evidence strongly supports a positive answer. Across the studies, IMT reliably improved inspiratory muscle strength, with gains seen in both early-stage and advanced COPD populations. Improvements in functional capacity, particularly in 6MWT performance, further demonstrated IMT's clinical relevance by enhancing patients' ability to perform daily tasks. Psychophysiological outcomes, including reductions in anxiety and improvements in perceived control over symptoms, indicate IMT's value as a holistic therapeutic intervention.

The significance of these findings lies in the potential for IMT to complement existing COPD management strategies. IMT appears particularly beneficial when combined with pulmonary rehabilitation or delivered through digital and biofeedback-enhanced formats. These insights highlight IMT's potential as a flexible, accessible and patient-centred intervention that can be adapted to various clinical environments.

In conclusion, this systematic review demonstrates that IMT is a valuable addition to COPD care. It provides measurable improvements in respiratory mechanics, functional performance and psychosocial wellbeing. The findings underscore the importance of incorporating IMT into rehabilitation pathways and support the need for further research to refine training protocols, enhance delivery methods and ensure long-term effectiveness. This study contributes

meaningful evidence to the field of respiratory rehabilitation and provides a foundation for future innovations in COPD management.

References

- Afifi, M., Stryhn, H. and Sánchez, J. (2023). Data extraction and comparison for complex systematic reviews: a step-by-step guideline and an implementation example using open-source software. *Systematic Reviews*, [online] 12(1). doi:<https://doi.org/10.1186/s13643-023-02322-1>.
- Agarwal, A.K., Raja, A. and Brown, B.D. (2023). *Chronic obstructive pulmonary disease (COPD)*. [online] National Library of Medicine. Available at: <https://www.ncbi.nlm.nih.gov/books/NBK559281/>.
- Almutairi, R., Alsarraf, A., Alkandari, D., Ashkanani, H. and Albazali, A. (2024). Dissecting through the literature: A review of the critical appraisal process. *Cureus*, [online] 16(5). doi:<https://doi.org/10.7759/cureus.59658>.
- Álvarez-Herms, J., Julià-Sánchez, S., Corbi, F., Odriozola-Martínez, A. and Burtcher, M. (2019). Putative Role of Respiratory Muscle Training to Improve Endurance Performance in Hypoxia: A Review. *Frontiers in Physiology*, 9. doi:<https://doi.org/10.3389/fphys.2018.01970>.
- Ammous, O., Feki, W., Lotfi, T., Khamis, A.M., Gosselink, R., Rebai, A. and Kammoun, S. (2023). Inspiratory muscle training, with or without concomitant pulmonary rehabilitation, for chronic obstructive pulmonary disease (COPD). *The Cochrane Database of Systematic Reviews*, [online] 2023(1), p.CD013778. doi:<https://doi.org/10.1002/14651858.CD013778.pub2>.
- Arena, R., Myers, J., Williams, M.A., Gulati, M., Kligfield, P., Balady, G.J., Collins, E. and Fletcher, G. (2007). Assessment of Functional Capacity in Clinical and Research Settings. *Circulation*, 116(3), pp.329–343. doi:<https://doi.org/10.1161/circulationaha.106.184461>.
- Beaumont, M., Forget, P., Couturaud, F. and Reyckler, G. (2018). Effects of inspiratory muscle training in COPD patients: A systematic review and meta-analysis. *The Clinical Respiratory Journal*, 12(7), pp.2178–2188. doi:<https://doi.org/10.1111/crj.12905>.
- Beaumont, M., Mialon, P., Ber-Moy, C.L., Lochon, C., Péran, L., Pichon, R., Gut-Gobert, C., Leroyer, C., Morelot-Panzini, C. and Couturaud, F. (2015). Inspiratory muscle training during pulmonary rehabilitation in chronic obstructive pulmonary disease. *Chronic Respiratory Disease*, 12(4), pp.305–312. doi:<https://doi.org/10.1177/1479972315594625>.
- Blakey, J., Hodgson, D. and Bolton, C.E. (2017). Inspiratory muscle training for chronic obstructive pulmonary disease. *Cochrane Database of Systematic Reviews*.

doi:<https://doi.org/10.1002/14651858.cd009428.pub2>.

Boers, E., Barrett, M., Su, J.G., Benjafield, A.V., Sinha, S., Kaye, L., Zar, H.J., Vuong, V., Tellez, D., Gondalia, R., Rice, M.B., Nunez, C.M., Wedzicha, J.A. and Malhotra, A. (2023). Global Burden of Chronic Obstructive Pulmonary Disease through 2050. *JAMA Network Open*, [online] 6(12), p.e2346598. doi:<https://doi.org/10.1001/jamanetworkopen.2023.46598>.

Booth, A., Martyn-St James, M., Clowes, M. and Sutton, A. (2021). Systematic Approaches to a Successful Literature Review. *Systematic Approaches to a Successful Literature Review*, [online] 1(1), pp.1–100. Available at: <https://www.torrossa.com/it/resources/an/5282271>.

Bramer, W.M., De Jonge, G.B., Rethlefsen, M.L., Mast, F. and Kleijnen, J. (2018). A Systematic Approach to Searching: an Efficient and Complete Method to Develop Literature Searches. *Journal of the Medical Library Association*, 106(4), pp.531–541. doi:<https://doi.org/10.5195/jmla.2018.283>.

Braun, V. and Clarke, V. (2006). *Using thematic analysis in psychology*. [online] Qualitative Research in Psychology. Available at: <https://psycnet.apa.org/record/2006-06991-002>.

Büchter, R.B., Weise, A. and Pieper, D. (2020). Development, Testing and Use of Data Extraction Forms in Systematic reviews: a Review of Methodological Guidance. *BMC Medical Research Methodology*, [online] 20(1), pp.1–14. Available at: <https://bmcmmedresmethodol.biomedcentral.com/articles/10.1186/s12874-020-01143-3>.

Buran Cirak, Y., Yilmaz Yelvar, G.D. and Durustkan Elbasi, N. (2022). Effectiveness of 12-week inspiratory muscle training with manual therapy in patients with COPD: A randomized controlled study. *The Clinical Respiratory Journal*, 16(4), pp.317–328. doi:<https://doi.org/10.1111/crj.13486>.

Carrera-Rivera, A., Ochoa, W., Larrinaga, F. and Lasa, G. (2022). How-to Conduct a Systematic Literature review: a Quick Guide for Computer Science Research. *MethodsX*, 9(1), p.101895. doi:<https://doi.org/10.1016/j.mex.2022.101895>.

Chen, Q., Wu, X., Huang, Y. and Chen, L. (2024). Internet of Things-Based Home Respiratory Muscle Training for Patients with Chronic Obstructive Pulmonary Disease: A Randomized Clinical Trial. *International Journal of Chronic Obstructive Pulmonary Disease*, Volume 19, pp.1093–1103. doi:<https://doi.org/10.2147/copd.s454804>.

da Fontoura, F.F., Roncato, G., Meyer, G.M.B., da Luz Goulart, C., Spilimbergo, F.B.,

Cipriano Junior, G., Bernadeli, M.G., Rigatto, K. and Berton, D.C. (2025). Inspiratory Muscle Training on Exercise Capacity, Dyspnoea and Health Status in Pulmonary Hypertension: A Randomised Controlled Trial. *Respirology*. doi:<https://doi.org/10.1111/resp.70054>.

de Farias, C.A.C., Gualdi, L.P., da Silva, S.B., Parreira, V.F., Montemezzo, D., Resqueti, V.R. and Fregonezi, G.A.F. (2019). Effects of different modalities of inspiratory muscle training as an add-on to conventional treatment of patients with chronic obstructive pulmonary disease (COPD): study protocol for a randomized controlled trial. *Trials*, 20(1). doi:<https://doi.org/10.1186/s13063-019-3271-1>.

Del Buono, M.G., Arena, R., Borlaug, B.A., Carbone, S., Canada, J.M., Kirkman, D.L., Garten, R., Rodriguez-Miguel, P., Guazzi, M., Lavie, C.J. and Abbate, A. (2019). Exercise Intolerance in Patients With Heart Failure. *Journal of the American College of Cardiology*, [online] 73(17), pp.2209–2225. doi:<https://doi.org/10.1016/j.jacc.2019.01.072>.

Dellweg, D., Reissig, K., Hoehn, E., Siemon, K. and Haidl, P. (2017). Inspiratory muscle training during rehabilitation in successfully weaned hypercapnic patients with COPD. *Respiratory Medicine*, 123, pp.116–123. doi:<https://doi.org/10.1016/j.rmed.2016.12.006>.

DeMars, M.M. and Perruso, C. (2022). MeSH and text-word search strategies: Precision, recall, and their implications for library instruction. *Journal of the Medical Library Association*, 110(1), pp.23–33. doi:<https://doi.org/10.5195/jmla.2022.1283>.

Dosbaba, F., Hartman, M., Formiga, M.F., Vlazna, D., Mináriková, J., Plutinsky, M., Brat, K., Su, J.J., Cahalin, L.P. and Batalik, L. (2025). Long-Term Efficacy of Novel and Traditional Home-Based, Remote Inspiratory Muscle Training in COPD: A Randomized Controlled Trial. *Journal of Clinical Medicine*, [online] 14(17), p.6099. doi:<https://doi.org/10.3390/jcm14176099>.

Dourado, I.M., Goulart, C. da L., Santos-de-Araújo, A.D., Marinho, R.S., Garcia-Araujo, A.S., Roscani, M.G., Trimer, R., da Silva, A.L.G., Mendes, R.G. and Borghi-Silva, A. (2025). Distance travelled in the six-minute walk test in patients with chronic obstructive pulmonary disease as a predictor of mortality. *BMC Pulmonary Medicine*, [online] 25(1). doi:<https://doi.org/10.1186/s12890-025-03721-x>.

Eldredge, J. (2024). *Critical Appraisal*. [online] [www.ncbi.nlm.nih.gov](https://www.ncbi.nlm.nih.gov/books/NBK603121/). Available at: <https://www.ncbi.nlm.nih.gov/books/NBK603121/>.

Ferguson, S.K., Miller, M., Yeager, L., Wislowski, A., Subudhi, A. and Roach, R.C. (2025). Impact of respiratory muscle training on exercise tolerance in hypobaric hypoxia: A pilot

study in adult males. *Physiological Reports*, 13(20). doi:<https://doi.org/10.14814/phy2.70613>.

Gea, J., Pascual, S., Casadevall, C., Orozco-Levi, M. and Barreiro, E. (2015). Muscle dysfunction in chronic obstructive pulmonary disease: update on causes and biological findings. *Journal of Thoracic Disease*, [online] 7(10), pp.E418–E438. doi:<https://doi.org/10.3978/j.issn.2072-1439.2015.08.04>.

Global Initiative for Chronic Obstructive Lung Disease (GOLD) (2023). *GLOBAL STRATEGY FOR PREVENTION, DIAGNOSIS AND MANAGEMENT OF COPD: 2023 Report*. [online] Global Initiative for Chronic Obstructive Lung Disease - GOLD. Available at: <https://goldcopd.org/2023-gold-report-2/>.

Halbert, R.J., Natoli, J.L., Gano, A., Badamgarav, E., Buist, A.S. and Mannino, D.M. (2006). Global burden of COPD: systematic review and meta-analysis. *European Respiratory Journal*, [online] 28(3), pp.523–532. doi:<https://doi.org/10.1183/09031936.06.00124605>.

Hariton, E. and Locascio, J.J. (2018). Randomised Controlled Trials - the Gold Standard for Effectiveness Research. *BJOG: an International Journal of Obstetrics & Gynaecology*, [online] 125(13), p.1716. doi:<https://doi.org/10.1111/1471-0528.15199>.

Health Education England (2020). *Respiratory disease*. [online] Health Education England. Available at: <https://www.hee.nhs.uk/our-work/population-health/respiratory-disease>.

Henriques, H.R., Correia, A., Santos, T., Faria, J., Sousa, D., Portela, J. and Teixeira, J. (2024). Nursing interventions to promote dyspnea self-management of complex chronic patients: An integrated review. *International Journal of Nursing Sciences*, [online] 11(2). doi:<https://doi.org/10.1016/j.ijnss.2024.03.008>.

İrem Hüzmeli, Nihan Katayıfçı, Fatih Yalçın and Esra Doğru Hüzmeli (2024). Effects of Different Inspiratory Muscle Training Protocols on Exercise Capacity, Respiratory Muscle Strength, and Health-Related Quality of Life in Patients with Hypertension. *International journal of clinical practice (Esher)*, 2024, pp.1–13. doi:<https://doi.org/10.1155/2024/4136457>.

Iwakura, M., Wakasa, M., Okura, K., Kawagoshi, A., Sugawara, K., Takahashi, H. and Shioya, T. (2021). Functionally relevant threshold of inspiratory muscle strength in patients with chronic obstructive pulmonary disease. *Respiratory Medicine*, 188, p.106625. doi:<https://doi.org/10.1016/j.rmed.2021.106625>.

JBİ (2020a). *CHECKLIST FOR QUASI- EXPERIMENTAL STUDIES (NON-RANDOMIZED EXPERIMENTAL STUDIES) Critical Appraisal tools for use in JBİ Systematic Reviews*

Critical Appraisal Checklist for Quasi-Experimental Studies -2. [online] Available at: https://jbi.global/sites/default/files/2020-07/Checklist_for_Quasi-Experimental_Appraisal_Tool.pdf.

JBİ (2020b). *CHECKLIST FOR RANDOMIZED CONTROLLED TRIALS Critical Appraisal tools for use in JBİ Systematic Reviews*. [online] Available at: https://jbi.global/sites/default/files/2020-08/Checklist_for_RCTs.pdf.

Joanna Briggs Institute (2017). *Checklist for Analytical Cross Sectional Studies Critical Appraisal Checklist for Analytical Cross Sectional Studies 2*. [online] Available at: https://jbi.global/sites/default/files/2019-05/JBI_Critical_Appraisal-Checklist_for_Analytical_Cross_Sectional_Studies2017_0.pdf.

Joanna Briggs Institute (2020). *Critical Appraisal Tools*. [online] JBİ. Available at: <https://jbi.global/critical-appraisal-tools>.

Khalil, M., Wagih, K. and Mahmoud, O. (2014). Evaluation of maximum inspiratory and expiratory pressure in patients with chronic obstructive pulmonary disease. *Egyptian Journal of Chest Diseases and Tuberculosis*, 63(2), pp.329–335. doi:<https://doi.org/10.1016/j.ejcdt.2014.01.010>.

Kowalski, T., Rodrigues, G.D. and Zanini, M. (2025). Application of respiratory muscle training for improved intermittent exercise performance in team sports: a narrative review. *Frontiers in Sports and Active Living*, 7. doi:<https://doi.org/10.3389/fspor.2025.1632207>.

Kulakiewicz, A., Baker, C. and Macdonald, M. (2021). Support for people with chronic obstructive pulmonary disease. *commonslibrary.parliament.uk*. [online] Available at: <https://commonslibrary.parliament.uk/research-briefings/cdp-2021-0188/>.

Lalwani, N. (2025). Plagiarism in Publications: All about Being Fair! *Indian journal of radiology and imaging - new series/Indian journal of radiology and imaging/Indian Journal of Radiology & Imaging*, [online] 35(S 01), pp.S36–S45. doi:<https://doi.org/10.1055/s-0044-1791745>.

Langer, D., Ciavaglia, C., Faisal, A., Webb, K.A., Neder, J.A., Gosselink, R., Dacha, S., Topalovic, M., Ivanova, A. and O'Donnell, D.E. (2018). Inspiratory muscle training reduces diaphragm activation and dyspnea during exercise in COPD. *Journal of Applied Physiology*, 125(2), pp.381–392. doi:<https://doi.org/10.1152/japplphysiol.01078.2017>.

Lee, C.-T., Chien, J.-Y., Hsu, M.-J., Wu, H.-D. and Wang, L.-Y. (2021). Inspiratory muscle

activation during inspiratory muscle training in patients with COPD. *Respiratory Medicine*, 190, p.106676. doi:<https://doi.org/10.1016/j.rmed.2021.106676>.

Li, H., Gao, T., Fang, W., Xian-Yu, C., Deng, N., Zhang, C. and Niu, Y. (2022). Global, regional and national burden of chronic obstructive pulmonary disease over a 30-year period: Estimates from the 1990 to 2019 Global Burden of Disease Study. *Respirology*, 28(1). doi:<https://doi.org/10.1111/resp.14349>.

Lima, T.B.W. e, Silva, B.B. dos S., Souza, A.P.S. de, Aires, D.M.F. and Fagundes, M.G. (2025). The effect of inspiratory muscle training on the inspiratory muscle metaboreflex: A systematic review. *Canadian Journal of Respiratory Therapy*, [online] 61. doi:<https://doi.org/10.29390/001c.132324>.

MacFarlane, A., Russell-Rose, T. and Shokraneh, F. (2022). Search Strategy Formulation for Systematic Reviews: Issues, Challenges and Opportunities. *Intelligent Systems with Applications*, 15(1). doi:<https://doi.org/10.1016/j.iswa.2022.200091>.

McDonagh, M., Peterson, K., Raina, P., Chang, S. and Shekelle, P. (2013). *Avoiding Bias in Selecting Studies*. [online] National Library of Medicine. Available at: <https://www.ncbi.nlm.nih.gov/books/NBK126701/>.

Mengist, W., Soromessa, T. and Legese, G. (2020). Method for Conducting Systematic Literature Review and Meta-Analysis for Environmental Science Research. *MethodsX*, [online] 7(7), pp.1–11. doi:<https://doi.org/10.1016/j.mex.2019.100777>.

Montes, M., Perez-Padilla, R., Celli, B., Aaron, S.D., Wehrmeister, F.C., Amaral, A.F.S., Mannino, D., Zheng, J., Salvi, S., Obaseki, D., Buist, A.S. and Menezes, A. (2025). The global burden of COPD: epidemiology and effect of prevention strategies. *PubMed*. [online] doi:[https://doi.org/10.1016/s2213-2600\(24\)00339-4](https://doi.org/10.1016/s2213-2600(24)00339-4).

Moseley, A.M., Elkins, M.R., Van der Wees, P.J. and Pinheiro, M.B. (2019). Using research to guide practice: The Physiotherapy Evidence Database (PEDro). *Brazilian Journal of Physical Therapy*, [online] 24(5). doi:<https://doi.org/10.1016/j.bjpt.2019.11.002>.

National Library of Medicine (2025). *PubMed*. [online] National library of medicine. Available at: <https://pubmed.ncbi.nlm.nih.gov/>.

O'Donnell, D.E., Milne, K.M., James, M.D., de Torres, J.P. and Neder, J.A. (2019). Dyspnea in COPD: New Mechanistic Insights and Management Implications. *Advances in Therapy*, [online] 37(1), pp.41–60. doi:<https://doi.org/10.1007/s12325-019-01128-9>.

Oermann, M.H., Wrigley, J., Nicoll, L.H., Ledbetter, L.S., Carter-Templeton, H. and Edie, A.H. (2021). Integrity of Databases for Literature Searches in Nursing. *Advances in Nursing Science*, [online] 44(2), pp.102–110. doi:<https://doi.org/10.1097/ANS.0000000000000349>.

Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., Chou, R., Glanville, J., Grimshaw, J.M., Hróbjartsson, A., Lalu, M.M., Li, T., Loder, E.W., Mayo-Wilson, E., McDonald, S. and McGuinness, L.A. (2021a). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *British Medical Journal*, [online] 372(71). doi:<https://doi.org/10.1136/bmj.n71>.

Page, M.J., Moher, D., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., Chou, R., Glanville, J., Grimshaw, J.M., Hróbjartsson, A., Lalu, M.M., Li, T., Loder, E.W., Mayo-Wilson, E., McDonald, S. and McGuinness, L.A. (2021b). PRISMA 2020 Explanation and elaboration: Updated Guidance and Exemplars for Reporting Systematic Reviews. *British Medical Journal*, 372(160). doi:<https://doi.org/10.1136/bmj.n160>.

Pham, H.Q., Pham, K.H.T., Ha, G.H., Pham, T.T., Nguyen, H.T., Nguyen, T.H.T. and Oh, J.-K. (2024). Economic burden of chronic obstructive pulmonary disease: A systematic review. *Tuberculosis and Respiratory Diseases*, [online] 87(3), pp.234–251. doi:<https://doi.org/10.4046/trd.2023.0100>.

Pleasant, R., Riley, I. and Mannino, D. (2016). Defining and targeting health disparities in chronic obstructive pulmonary disease. *International Journal of Chronic Obstructive Pulmonary Disease*, [online] Volume 11(11), pp.2475–2496. doi:<https://doi.org/10.2147/copd.s79077>.

Poddighe, D., Van Hollebeke, M., Rodrigues, A., Hermans, G., Testelmans, D., Kalkanis, A., Clerckx, B., Gayan-Ramirez, G., Gosselink, R. and Langer, D. (2024). Respiratory muscle dysfunction in acute and chronic respiratory failure: how to diagnose and how to treat? *European Respiratory Review*, 33(174), p.240150. doi:<https://doi.org/10.1183/16000617.0150-2024>.

Pottier, P., Lagisz, M., Burke, S., Drobnjak, S.M., Downing, P.A., Macartney, E.L., Martinig, A.R., Mizuno, A., Morrison, K., Pollo, P., Ricolfi, L., Tam, J., Williams, C., Yang, Y. and Nakagawa, S. (2024). Title, abstract and keywords: a practical guide to maximize the visibility and impact of academic papers. *Proceedings of the Royal Society B Biological Sciences*, [online] 291(2027). doi:<https://doi.org/10.1098/rspb.2024.1222>.

ProQuest (2024). *ProQuest | Better research, better learning, better insights*. [online] [www.proquest.com](https://www.proquest.com/index). Available at: <https://www.proquest.com/index>.

Qi, X.-H., Ren, H.-M., Wang, N., Shi, X.-P., Wang, X.-X. and Wang, Y. (2025). Effects of respiratory muscle training on clinical outcomes in patients with chronic obstructive pulmonary disease: A systematic review and meta-analysis. *Annals of Thoracic Medicine*, [online] 20(4), pp.213–221. doi:https://doi.org/10.4103/atm.atm_230_24.

Ramsook, A.H., Molgat-Seon, Y., Schaeffer, M.R., Wilkie, S.S., Camp, P.G., Reid, W.D., Romer, L.M. and Guenette, J.A. (2017). Effects of inspiratory muscle training on respiratory muscle electromyography and dyspnea during exercise in healthy men. *Journal of Applied Physiology*, [online] 122(5), pp.1267–1275. doi:<https://doi.org/10.1152/jappphysiol.00046.2017>.

Randles, R. and Finnegan, A. (2023). Guidelines for Writing a Systematic Review. *Nurse Education Today*, [online] 125(125), pp.105803–105803. doi:<https://doi.org/10.1016/j.nedt.2023.105803>.

Réginault, T., Roberto Martinez Alejos, Coueron, R., Burle, J., Boyer, A., Frison, E. and Vargas, F. (2024). Impacts of three inspiratory muscle training programs on inspiratory muscles strength and endurance among intubated and mechanically ventilated patients with difficult weaning: a multicentre randomized controlled trial. *Journal of Intensive Care*, [online] 12(1). doi:<https://doi.org/10.1186/s40560-024-00741-3>.

Ren, Z., Guo, J., He, Y., Luo, Y. and Wu, H. (2025). Effects of Inspiratory Muscle Training on Respiratory Muscle Strength, Lactate Accumulation and Exercise Tolerance in Amateur Runners: A Randomized Controlled Trial. *Life*, [online] 15(5), p.705. doi:<https://doi.org/10.3390/life15050705>.

Resnik, D. (2020). *What is ethics in research & why is it important?* [online] National Institute of Environmental Health Sciences. Available at: <https://www.niehs.nih.gov/research/resources/bioethics/whatis>.

Rossi, A. and Aisanov, Z. (2015). Mechanisms, assessment and therapeutic implications of lung hyperinflation in COPD. *Respiratory Medicine*, [online] 109(7), pp.785–802. doi:<https://doi.org/10.1016/j.rmed.2015.03.010>.

Saey, D., Gagnon, P., Guenette, J., Langer, D., Laviolette, L., Mainguy, V., Maltais, F. and Ribeiro, F. (2014). Pathogenesis of hyperinflation in chronic obstructive pulmonary disease. *International Journal of Chronic Obstructive Pulmonary Disease*, [online] 9(1), p.187.

doi:<https://doi.org/10.2147/copd.s38934>.

Santana, P.V. and Albuquerque, A.L.P. de (2018). Respiratory muscles in COPD: be aware of the diaphragm. *Jornal Brasileiro de Pneumologia*, 44(1), pp.1–2.

doi:<https://doi.org/10.1590/s1806-37562018000010001>.

Schmidt, L., Finnerty, N., Elmore, R.W., Olorisade, B.K., Thomas, J. and Higgins, J.P.T. (2023). Data Extraction Methods for Systematic Review (semi)automation: Update of a Living Systematic Review. *F1000Research*, [online] 10(401), pp.401–401.

doi:<https://doi.org/10.12688/f1000research.51117.2>.

Shaheen, N., Shaheen, A., Ramadan, A., Hefnawy, M.T., Ramadan, A., Ibrahim, I., Hassanein, M., Ashour, M.E. and Flouty, O. (2023). Appraising Systematic reviews: a Comprehensive Guide to Ensuring Validity and Reliability. *Frontiers in Research Metrics and Analytics*, 8(8). doi:<https://doi.org/10.3389/frma.2023.1268045>.

Shenoy, M.A. and Paul, V. (2023). *Pulmonary Rehabilitation*. [online] PubMed. Available at: <https://www.ncbi.nlm.nih.gov/books/NBK563166/>.

Shioya, T., Sato, S., Iwakura, M., Takahashi, H., Terui, Y., Uemura, S. and Satake, M. (2018). Improvement of physical activity in chronic obstructive pulmonary disease by pulmonary rehabilitation and pharmacological treatment. *Respiratory Investigation*, 56(4), pp.292–306. doi:<https://doi.org/10.1016/j.resinv.2018.05.002>.

Snell, N., Strachan, D., Hubbard, R., Gibson, J., Gruffydd-Jones, K. and Jarrold, I. (2016). Epidemiology of Chronic Obstructive Pulmonary Disease (COPD) in the uk: Findings from the British Lung Foundation's 'Respiratory Health of the Nation' Project. *Thorax*, [online] 71(3), pp. A20.1-A20. doi:<https://doi.org/10.1136/thoraxjnl-2016-209333.38>.

Thomas, M., Decramer, M. and O'Donnell, D.E. (2013). No room to breathe: the importance of lung hyperinflation in COPD. *Primary Care Respiratory Journal*, [online] 22(1), pp.101–111. doi:<https://doi.org/10.4104/pcrj.2013.00025>.

Tod, D., Booth, A. and Smith, B. (2021). Critical Appraisal. *International Review of Sport and Exercise Psychology*, 15(1), pp.52–72. doi:<https://doi.org/10.1080/1750984x.2021.1952471>.

Tonga, K.O. and Oliver, B.G. (2023). Effectiveness of Pulmonary Rehabilitation for Chronic Obstructive Pulmonary Disease Therapy: Focusing on Traditional Medical Practices. *Journal of Clinical Medicine*, [online] 12(14), p.4815. doi:<https://doi.org/10.3390/jcm12144815>.

Torres-Castro, R., Caicedo-Trujillo, S., Gimeno-Santos, E., Gutiérrez-Arias, R., Alsina-Restoy, X., Vasconcello-Castillo, L., Seron, P., Spruit, M.A., Blanco, I. and Vilaró, J. (2025). Effectiveness of inspiratory muscle training in patients with a chronic respiratory disease: an overview of systematic reviews. *Frontiers in sports and active living*, [online] 7, p.1549652. doi:<https://doi.org/10.3389/fspor.2025.1549652>.

Tounsi, B., Acheche, A., Lelard, T., Tabka, Z., Trabelsi, Y. and Ahmaidi, S. (2021). Effects of specific inspiratory muscle training combined with whole-body endurance training program on balance in COPD patients: Randomized controlled trial. *PLOS ONE*, 16(9), p.e0257595. doi:<https://doi.org/10.1371/journal.pone.0257595>.

Tripathy, J.P. (2013). Secondary Data Analysis: Ethical Issues and Challenges. *Iranian Journal of Public Health*, [online] 42(12), p.1478. Available at: <https://pmc.ncbi.nlm.nih.gov/articles/PMC4441947/>.

UK Research Integrity Office (2023). *Code of Practice for Research*. [online] Available at: <https://ukrio.org/wp-content/uploads/UKRIO-Code-of-Practice-for-Research.pdf>.

Vázquez-Gandullo, E., Hidalgo-Molina, A., Montoro-Ballesteros, F., Morales-González, M., Muñoz-Ramírez, I. and Arnedillo-Muñoz, A. (2022). Inspiratory Muscle Training in Patients with Chronic Obstructive Pulmonary Disease (COPD) as Part of a Respiratory Rehabilitation Program Implementation of Mechanical Devices: A Systematic Review. *International Journal of Environmental Research and Public Health*, 19(9), p.5564. doi:<https://doi.org/10.3390/ijerph19095564>.

Wang, K., Zeng, G., Li, R., Luo, Y., Wang, M., Hu, Y., Xu, W., Zhou, L., Chen, R. and Chen, X. (2017). Cycle ergometer and inspiratory muscle training offer modest benefit compared with cycle ergometer alone: a comprehensive assessment in stable COPD patients. *International Journal of Chronic Obstructive Pulmonary Disease*, Volume 12, pp.2655–2668. doi:<https://doi.org/10.2147/copd.s140093>.

World Health Organization (2024). *Chronic obstructive pulmonary disease (COPD)*. [online] World Health Organization. Available at: [https://www.who.int/news-room/fact-sheets/detail/chronic-obstructive-pulmonary-disease-\(copd\)](https://www.who.int/news-room/fact-sheets/detail/chronic-obstructive-pulmonary-disease-(copd)).

Wu, W., Guan, L., Zhang, X., Li, X., Yang, Y., Guo, B., Ou, Y., Lin, L., Zhou, L. and Chen, R. (2017). Effects of two types of equal-intensity inspiratory muscle training in stable patients with chronic obstructive pulmonary disease: A randomized controlled trial. *Respiratory Medicine*, 132, pp.84–91. doi:<https://doi.org/10.1016/j.rmed.2017.10.001>.

Xie, J., Zhu, Y., Wang, Y., Mo, Y., Shi, X., Liang, W.-M., Ren, F.-F., Bai, Z. and Nie, F. (2025). Effects of pulmonary rehabilitation combined with inspiratory muscle training on lung function and exercise capacity in older patients with COPD: a systematic review and meta-analysis. *Frontiers in Medicine*, 12. doi:<https://doi.org/10.3389/fmed.2025.1621375>.

Xiong, T., Bai, X., Wei, X., Wang, L., Li, F., Shi, H. and Shi, Y. (2023). Exercise Rehabilitation and Chronic Respiratory Diseases: Effects, Mechanisms, and Therapeutic Benefits. *International Journal of Chronic Obstructive Pulmonary Disease*, [online] Volume 18, pp.1251–1266. doi:<https://doi.org/10.2147/copd.s408325>.

Yonis, A., Dean, S.G., Warren, F.C., Taylor, R.S., Levack, W. and Hay-Smith, J. (2025). Navigating blinding challenges in complex intervention trials: insights from a UK researcher survey. *Trials*, 26(1). doi:<https://doi.org/10.1186/s13063-025-09223-9>.

Appendix-A: - DATA Extraction Table

Author / Year	Country	Study Design	Sample Size & Characteristics	Intervention (IMT Type, Intensity, Duration)	Comparator	Outcome Measures	Key Findings
Tounsi et al. (2021)	Tunisia	RCT	n=30; stable COPD	IMT + endurance training; 30–60% PImax; 8 weeks	Endurance training only	PImax, Berg Balance Scale, ABC Scale, 6MWT	Significant improvements in PImax, balance, and functional capacity in IMT+ET group
de Farias et al. (2019)	Brazil	RCT	Planned n=60 COPD	IMT protocol; 30% PImax 5×/week	–	PImax,	PImax, IMT
Wang et al. (2017)	China	RCT	n=81 COPD	IMT + cycle ergometer training; 60% PImax; 8 weeks	CET only / Control	PImax, dyspnoea, QoL, lung function	IMT+CET showed greater improvements in PImax, dyspnoea, QoL vs CET alone
Wu et al. (2017)	China	RCT	n=60 COPD	Resistive IMT vs threshold IMT; 60% PImax; 8 weeks	Non-intervention control	PImax, CRQ, dyspnoea, 6MWT	Resistive IMT produced superior improvements in dyspnoea & exercise capacity
Dosbaba et al. (2025)	Czech Republic (Czechia)	RCT	n=78 COPD	TIRE IMT vs threshold IMT vs sham; home-	Sham IMT	MIP, SMIP, dyspnoea	TIRE showed significantly greater long-term gains in

				based 24 weeks			inspiratory strength
Dellweg et al. (2017)	Germany	RCT	n=29 hypercapnic COPD post-ventilation	IMT at 50% PImax; 6 weeks	Sham IMT	PImax, 6MWT, hypercapnia status	Significant PImax & 6MWT improvement; beneficial for severe COPD patients
Lee et al. (2021)	Taiwan	Quantitative observational	n=30 COPD with inspiratory weakness	IMT at 30% & 50% PImax EMG analysis	No comparator	Diaphragm & SCM EMG activation	Higher IMT intensities increased accessory muscle activation
Chen et al. (2024)	Taiwan	RCT	n=74 COPD	IoT-based home IMT/EMT system; 12 weeks	Usual care	FEV1/FVC, PImax, dyspnoea, CAT, HAMA	Significant improvements in respiratory function, dyspnoea, anxiety & QoL
Beaumont et al. (2015)	France	RCT	n=32 COPD without inspiratory muscle weakness	Threshold IMT; 50% PImax; 12 weeks	Sham IMT	PImax, dyspnoea (MDP), 6MWT	Benefits limited overall but improved outcomes in severe subgroups
Cirak et al. (2022)	Turkey	RCT	n=70 COPD	IMT + manual therapy; 30% PImax; 8 weeks	IMT alone	PImax, FEV1, 6MWT, SGRQ	Combined treatment yielded superior improvements in strength & QoL

Appendix-B: - Evaluation of Quantitative Studies Using the JBI Tool

JBI Questions	Study 1 Tounsi 2021	Study 2 de Farias 2019	Study 3 Wang 2017	Study 4 Wu 2017	Study 5 Dosba ba 2025	Study 6 Dellweg 2017	Study 7 Lee 2021	Study 8 Chen 2024	Study 9 Beaumo nt 2015	Study 10 Cirak 2022
1. Was randomisation used appropriately?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2. Was allocation concealed?	Unclear	N/A	Unclear	Unclear	Yes	Yes	N/A	Unclear	Unclear	Unclear
3. Were groups similar at baseline?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
4. Were participants blind to treatment assignment?	No	N/A	No	No	No	No	N/A	No	No	No
5. Were those delivering treatment blind?	No	N/A	No	No	No	No	N/A	No	No	No
6. Were outcome assessors blind?	Unclear	N/A	Unclear	Unclear	Unclear	Unclear	N/A	Unclear	Unclear	Unclear
7. Were groups treated identically other than intervention?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
8. Was follow-up complete and accounted for?	Yes	unclear	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

9. Were participants analysed in the groups they were assigned to?	Yes	N/A	Yes	Yes	Yes	Yes	N/A	Yes	Yes	Yes
10. Were outcome measures valid and reliable?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
11. Was appropriate statistical analysis used?	Yes	N/A	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
12. Were confounding factors identified and controlled?	Unclear	No	Unclear	Unclear	Yes	Unclear	No	Unclear	Unclear	Unclear
13. Were subpopulations identified objectively (if applicable)?	N/A	N/A	N/A	N/A	N/A	N/A	Yes	Unclear	N/A	N/A
Overall Quality Rating	Moderate-High	Moderate	High	High	High	Moderate-High	Moderate	High	Moderate	Moderate-High