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# Current developments and future directions in respiratory physiotherapy

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**Respiratory physiotherapists have a key role within the integrated care continuum of patients with respiratory diseases. The current review highlights the diversity of the profession and addresses future research directions in respiratory physiotherapy.** <https://bit.ly/39jgCOK>

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**ABSTRACT** Respiratory physiotherapists have a key role within the integrated care continuum of patients with respiratory diseases. The current narrative review highlights the profession's diversity, summarises the current evidence and practice, and addresses future research directions in respiratory physiotherapy. Herein, we describe an overview of the areas that respiratory physiotherapists can act in the integrated care of patients with respiratory diseases based on the Harmonised Education in Respiratory Medicine for European Specialists syllabus. In addition, we highlight areas in which further evidence needs to be gathered to confirm the effectiveness of respiratory therapy techniques. Where appropriate, we made recommendations for clinical practice based on current international guidelines.

## Introduction

In recent years, respiratory physiotherapists have established an important role within the integrated care continuum of patients with respiratory diseases, ranging from chronic outpatient care (*e.g.* exercise training) to critically ill care in the intensive care unit (ICU) (*e.g.* early mobilisation). Respiratory physiotherapists are currently closely involved in the multidisciplinary care of patients suffering and recovering from coronavirus disease 2019 [1–3]. Depending on the condition and setting, respiratory physiotherapists will address multiple treatable traits including (but not limited to) impairment of mucus evacuation, atelectasis, breathing asynchrony, respiratory and peripheral muscle weakness, deconditioning and physical inactivity. Respiratory physiotherapy is acknowledged as a subspecialty of physiotherapy in various countries, but the availability and content of specialty training is very heterogeneous. In an

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attempt to harmonise this training, the European Respiratory Society (ERS) recently developed and published the Harmonised Education in Respiratory Medicine for European Specialists (HERMES) physiotherapy curriculum, which intends to be a freely available core syllabus for postgraduate training in respiratory physiotherapy [4, 5]. This review will summarise all modules from the HERMES physiotherapy curriculum that cover physiotherapy interventions. The HERMES is an initiative from the ERS Physiotherapists group and ERS leadership to standardise core knowledge, skills, attitudes and competencies that physiotherapists require to assess, treat and follow patients with respiratory diseases, and cover different aspects of respiratory physiotherapy interventions [6]. Thus, in this review we provide an overview of current practices across different areas of respiratory physiotherapy and identify future research directions that can be used to strengthen the practice of respiratory physiotherapy based on the HERMES recommendations.

### Techniques for airway clearance

In healthy lungs, the body is able to remove inhaled particles, including microorganisms, by several mechanisms (*e.g.* mucociliary clearance, cough reflexes and actions of alveolar macrophages) [7–9]. In normal conditions, healthy mucus is a gel with low viscosity and elasticity that is easily drained by ciliary action. In contrast, mucus dysfunction has higher viscosity and elasticity and is more difficult to clear [7–9]. The conversion from healthy to pathologic mucus occurs through multiple mechanisms that change its properties (hydration and biochemical constituents), including increased mucus production, infiltration with inflammatory cells, and the increase of bronchovascular permeability [7–9]. The accumulation of mucus results from secretion overproduction and decreased clearance, promoting inflammation and recurrent respiratory exacerbations [7–9].

There is a wide array of airway clearance techniques that can be used to improve mucociliary clearance and can be grouped into the following categories: 1) manual techniques (low flow and high flow); and 2) techniques involving the use of devices (positive expiratory pressure (PEP) and oscillatory positive expiratory pressure). Table 1 provides a concise explanation of commonly used techniques such as the active cycle of breathing, autogenic drainage, PEP therapy, total slow expiration with open glottis

TABLE 1 Lexicon of airway clearance and breathing techniques

#### Airway clearance techniques

|                                                       |                                                                                                                                                                                                                                                                                                                                                                     |
|-------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Active cycle of breathing [10, 11]                    | A cycle of deep breathing exercises interspersed with breathing control, followed by the FET [a combination of 1 or 2 huffs <sup>#</sup> interspersed with periods of breathing control]                                                                                                                                                                            |
| Autogenic drainage [10, 11]                           | Composed of three phases: <ol style="list-style-type: none"> <li>1. unsticking the peripheral mucus by breathing at low lung volumes (below FRC)</li> <li>2. collecting the mucus in the middle airways by breathing at mid lung volumes close to FRC</li> <li>3. evacuating the secretions from the central airways by breathing at higher lung volumes</li> </ol> |
| Positive expiratory pressure therapy [10, 11]         | Provides a constant pressure to the airways throughout expiration using an expiratory resistance device with a one-way valve                                                                                                                                                                                                                                        |
| ELTGOL (total slow expiration with open glottis) [12] | The patient lies in a lateral decubitus position and breathes out slowly through an open glottis from FRC to residual volume                                                                                                                                                                                                                                        |
| Manually assisted cough [13, 14]                      | Thoracic or abdominal compression added to augment the expiratory effort of a cough                                                                                                                                                                                                                                                                                 |
| Mechanical insufflation-exsufflation [13, 14]         | A device gradually inflates the lungs using positive pressure, immediately follows an abrupt change to negative pressure that produces a rapid exhalation                                                                                                                                                                                                           |

#### Breathing strategies

|                               |                                                                                                                                                                                                                                                                                                   |
|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Incentive spirometry [10]     | Use of a handheld device that provides patients with visual feedback regarding their performance during deep breathing exercises; it can be provided by flow- or volume-based spirometers                                                                                                         |
| Deep breathing exercises [10] | Full inspiration to TLC, with or without a 2–3 s hold at the end of inspiration, followed by relaxed expiration<br>Adequate expiratory time is required to allow complete expiration<br>Compared to a rapid inspiration, a slow inspiration allows a more homogeneous distribution of ventilation |
| Positive pressure [10]        | Applying positive pressure throughout inspiration to the airways and lungs by asking the patients to breathe using a device that attaches to them <i>via</i> a face mask or a mouthpiece                                                                                                          |

FET: forced expiratory technique; FRC: functional residual capacity; TLC: total lung capacity. <sup>#</sup>: a huff is described as a deep inspiration followed by a forced expiration with the glottis open.

(ELTGOL), manually assisted cough, and mechanical insufflation-exsufflation. Airway clearance techniques aim to improve mucociliary transport to drain secretions effectively in individuals with excess secretions and/or sputum retention, optimise quality of life and reduce severity and frequency of exacerbations, independently of the disease that has produced the impairment. Various techniques are available that aim to modify secretions' viscoelasticity, increase gas-liquid interaction and facilitate drainage. Depending on the techniques chosen, the effects of airway clearance are based on producing changes in both lung volumes and expiratory flows. It can also include offering intra- and extrapulmonary vibrations and compressions of the rib cage [15].

Patients prone to the retention of secretions can benefit from airway clearance techniques regardless of the underlying respiratory disease [10, 16–20]. Despite lacking a robust evidence base, airway clearance techniques are part of standard management in patients with cystic fibrosis, bronchiectasis, neuromuscular diseases and selected patients with COPD [10, 16–20]. Studies suggest that these techniques help optimise quality of life, exercise capacity, and mucociliary clearance and sputum volumes/viscosities.

The largest body of evidence regarding the efficacy of airway clearance techniques has been accumulated in patients with cystic fibrosis [18–20]. The available data at this point does indicate that while airway clearance techniques seem effective in comparison to control treatments, no technique of airway clearance has been shown to be superior to any other [18–20].

Patients suffering from bronchiectasis may also benefit from airway clearance. Both PEP therapy and manual chest physiotherapy, including the ELTGOL technique (table 1), have proven effective [17]. Benefits in different outcomes have been demonstrated during stable and acute states. However, studies including long-term follow-up data are very limited, and the quality of available studies is, on average, low [21, 22].

In patients with COPD, airway clearance techniques (*e.g.* active cycle of breathing and autogenic drainage) (table 1) seem to be safe and offer some clinical outcomes such as short-term reductions in the need for increased ventilatory assistance, duration of ventilatory assistance, and hospital length of stay in both acute and stable disease. However, studies suggest that the benefits achieved may be small, especially if no pre-selection is made of patients prone to the retention of secretions [16].

In neuromuscular diseases, peripheral airway clearance techniques (*i.e.* secretion mobilisation) show some benefits, but quality of available evidence is again low [10]. Proximal airway drainage techniques (*i.e.* cough augmentation), high flow manual and mechanical techniques, such as manually assisted cough and mechanical insufflation-exsufflation, demonstrate better results (increase peak cough flow) compared with peripheral airway drainage, especially in patients with pronounced respiratory muscle weakness [10].

## **Respiratory muscle assessment and training, breathing strategies and techniques for lung expansion**

### ***Respiratory muscle assessment and training***

The respiratory pump is at the centre of the ventilatory system and ensures supply and removal of respiratory gases. Respiratory muscle weakness is frequently present in patients with respiratory symptoms, patients with neuromuscular diseases, and patients admitted to the ICU [23]. The potential value of implementing rehabilitative interventions for respiratory muscle conditioning is supported by observations showing that respiratory muscle weakness is associated with prolonged duration of mechanical ventilation, difficult weaning and increased ICU mortality [24, 25], as well as symptoms of exertional dyspnoea and exercise limitation in patients with chronic lung disease [23, 26].

In two recent systematic reviews, it was observed that inspiratory muscle training (IMT) in mechanically ventilated patients can improve respiratory muscle function and might facilitate weaning from mechanical ventilation [27, 28]. From the most recent meta-analyses in patients with COPD, it can be concluded that IMT can improve inspiratory muscle strength and endurance, functional exercise capacity, dyspnoea and quality of life when offered as a stand-alone intervention [29, 30]. However, the current evidence is inconclusive as to who might benefit most from additional respiratory muscle training as part of a comprehensive pulmonary rehabilitation programme. Nevertheless, recent evidence shows that in patients with COPD, IMT in association with exercise training may cause larger decreases in dyspnoea intensity at similar work rates compared to exercise training without the association of IMT [31].

Assessment prior to respiratory muscle conditioning interventions requires measurements of inspiratory muscle function (strength and endurance). These tests have also been proven to be responsive to evaluate changes in response to treatment within subjects [23]. Both maximum static inspiratory pressure that a subject can generate at the mouth and muscle endurance are typically measured in specialised pulmonary function laboratories [32]. Small hand-held devices have become commercially available for these purposes in recent years [33, 34]. These devices have made it easier to perform these tests in less specialised centres

or even in the home setting, thereby contributing to better diagnosis, patient phenotyping, assessment of treatment efficiency and patient follow-up [23]. Maximal inspiratory pressure can serve as a screening instrument to identify patients with respiratory muscle weakness and reference values were recently summarised [23, 35]. In the absence of conclusive evidence, values <70% of predicted normal values seem to be a good indicator of respiratory muscle weakness and can be considered when deciding on initiating treatment [23, 35]. In the ICU, it seems most useful to focus conditioning interventions on patients with weaning difficulties [27, 28]. Results of assessments should never be interpreted in isolation, but together with the overall clinical picture (pathology, symptoms and load/capacity balance during daily activities). Recommendations for patient assessment have recently been summarised in more detail in an ERS statement on respiratory muscle testing [23].

There are few studies available comparing different training devices or training protocols head to head [23]. Recommendations on preferred devices and training protocols for different purposes are therefore not supported by firm evidence. Three different types of loading have been used in most respiratory muscle training programmes over the past decades [23]. These approaches are either primarily aimed at improving muscle strength and endurance (intermediate flow/high pressure approaches such as targeted resistive loading and threshold loading) or muscle endurance only (high flow/low pressure approaches such as normocapnic hyperpnoea) [36]. For these different training modalities, devices are commercially available that allow controlled home-based training interventions to be offered. A fourth type of loading has gained popularity in recent years. This so-called tapered flow resistive loading can be regarded as a hybrid between threshold loading and targeted flow resistive loading [36]. Until recently, well-controlled respiratory muscle training interventions were mostly restricted to laboratory settings or specialised hospital environments and required extensive supervision to be performed effectively. Nowadays, effective and well-controlled training programmes can be offered, largely unsupervised in the patients' home environment [31]. Nowadays, direct feedback on key training parameters (number of repetitions, external resistance, volume response and work performed) is available both during and after training sessions. Direct feedback also allows frequent re-assessment of the patients training parameters for adjusting and progressing the training. This is of great importance for achieving optimal outcomes and can be performed largely by patients at home. These recent developments can improve guidance on training progression, increase patient motivation, and reduce time investment for both healthcare providers and patients. These methodological and technological improvements should contribute to facilitating implementation and the efficacy of respiratory muscle training interventions into clinical practice in the coming years.

In summary, weighing efforts against benefits, one might consider offering IMT to: 1) symptomatic patients with respiratory muscle weakness; 2) patients with weaning difficulties; 3) patients who are unable (or not yet able) to join a comprehensive pulmonary rehabilitation programme; and 4) patients who are motivated to optimise their gains in functional capacity during a pulmonary rehabilitation programme.

### ***Breathing strategies***

Lung hyperinflation is highly prevalent in patients with obstructive lung disease and occurs across the continuum of the disease [37]. A growing body of evidence suggests that dynamic hyperinflation contributes to dyspnoea and activity limitation [38, 39]. Several treatment options are available for the respiratory physiotherapist to assist overburdened respiratory muscles to better cope with increased loads during (exercise) breathing and improve (recovery from) symptoms during (and after) periods of physical exertion resulting in dyspnoea [40–43].

#### ***Deep and slow breathing***

Training patients to transiently breathe slowly and deeply during exercise should decrease hyperinflation, work of breathing, and improve symptoms and exercise capacity [41]. Some patients with severe airflow obstruction and lung hyperinflation that spontaneously use pursed lip breathing (PLB) successfully reduce expiratory flow limitation, decrease respiratory rate, and, therefore, experience improvements in dyspnoea at rest and during exercise [40]. Conversely, such findings are inconsistent in patients who do not adopt PLB spontaneously [44]. During PLB, patients perform a moderately active expiration through half-opened lips, thereby inducing expiratory mouth pressures of ~5 cmH<sub>2</sub>O [45]. It has been shown that slowing down expiratory flow may reduce airways' tendency to collapse and results in less air trapping [42, 43]. This is probably why the technique seems to be most effective in patients with severe loss of lung elastic recoil pressure and tracheobronchial collapse [44]. Adopting PLB at rest or during recovery periods (*i.e.* during resting periods of interval training sessions) reduces breathing frequency and increases tidal volume, while minute ventilation is usually maintained or slightly reduced [42]. Therefore, it can help patients reduce symptoms and normalise breathing pattern after a bout of high-intensity exercise. Reducing dead space and improving alveolar minute ventilation probably explains improvements in gas

exchange that are typically observed [42, 46]. These effects have also been observed when a slower and deeper breathing pattern was adopted without using PLB [47].

Studies on PLB that have been performed during exercise in small and heterogeneous samples show mixed results in terms of dyspnoea reduction and improvements in exercise capacity [40, 48–50]. SPAHIJA *et al.* [40] performed the only study (n=8) that measured changes in hyperinflation and respiratory muscle effort after PLB during constant work bicycle exercise. They found a strong correlation between improvements in dyspnoea sensation during exercise and both changes in end-expiratory lung volume and inspiratory muscle work occurring with PLB. Moreover, the improvement in dyspnoea during the cycling test tended to be greater in more hyperinflated patients. Further research will be needed to identify and select patients that might benefit from PLB and the role of PLB during exercise [44]. It will further be important to standardise the technique and to define the amount of training, instruction and reinforcement needed to apply it successfully [51]. Samples studied have been heterogeneous and there is a degree of uncertainty regarding the amount of supervision and training necessary to allow patients to execute the technique optimally.

Evidence on the usefulness of this breathing strategy in patient groups besides those with severe expiratory airflow limitation and hyperinflation is still scarce and warrants further investigation (*e.g.* interstitial lung disease and stroke) [52, 53].

COLLINS *et al.* [54] have used a computerised ventilation feedback intervention to slow the respiratory rate during exercise, combined with an exercise training programme. They showed reductions in respiratory rate, ventilation and dynamic hyperinflation at isotime during a constant load cycling task. These improvements were related to improvements in dyspnoea during exercise. The feasibility and persistence of these positive effects in the absence of the feedback still need to be determined to make this approach applicable in clinical practice.

#### *Techniques for lung expansion*

Deep breathing exercises and lung expansion techniques have been widely used to prevent complications in different chronic respiratory diseases and after surgical procedures [55–58]. However, their efficacy remains uncertain. These strategies include deep breathing exercises, incentive spirometers, or positive expiratory pressure (table 1) [55].

Deep breathing exercises are based on producing an active inspiration with a breath hold, permitting a maximum and slow breath, before a passive expiration. This technique can be applied in patients with drained and undrained pleural effusions; a survey has found that it is the most commonly used technique in these patients [56]. Deep breathing exercises have been evaluated in patients after upper abdominal surgery in a randomised control trial; results show that neither thoracoabdominal mechanics nor pulmonary complications were modified using this technique [58]. But conclusions of this work need to be interpreted with caution, as this study has important limitations, such as the use of unmatched groups for type of surgery, as well as an inadequate sample size for the selected end-point.

Incentive spirometry follows the same principle as deep breathing exercises, but using a device which provides visual feedback to improve patient motivation [57]. Incentive spirometry has been studied in patients after thoracotomy and lung resection, and it seems that higher risk patients can benefit from this technique to decrease post-operative pulmonary complications [57]. Nonetheless, regarding patients after upper abdominal surgery, the quality of the evidence is low [59]; one review underlines the urgent need to conduct well-designed trials in this field [59]. This review included 12 studies with general poor methodological quality, most studies were from the 1970s and 1980s. We need to consider that both incentive spirometry protocols and devices, as well as surgical procedures and respective pulmonary complications in these studies, are probably not comparable to our current clinical practice. Currently, clinical practice guidelines advise against the use of incentive spirometry in routine post-operative care [60].

Positive end-expiratory pressure has been shown to increase lung expansion and alveolar recruitment [61]. Positive end-expiratory pressure has been conducted in a study with mechanically ventilated patients submitted to coronary artery bypass grafting. It has been demonstrated that high levels of positive end-expiratory pressure (15 cmH<sub>2</sub>O) are beneficial for the improvement of gas exchange in those patients [62]. This technique has also been evaluated in patients after upper abdominal surgery, and no significant differences in lung expansion or post-operative pulmonary complications were observed compared with incentive spirometry [63].

#### *Body positioning techniques*

Forward leaning is (like with active expiration during PLB) often spontaneously used by patients to relieve dyspnoea, possibly by improving the diaphragm's length tension relationships [64–67]. The presence of

hyperinflation and paradoxical abdominal movements have been shown to decrease and be related to the relief of dyspnoea in this position [65]. Forward leaning is associated with a significant decrease in inspiratory muscle activation, better inspiratory muscle efficiency [65, 66], and significant improvements in the synchrony of the thoracoabdominal movements [65–67]. Besides, forward leaning with arm support allows accessory muscles (pectoralis minor and major) to significantly contribute to rib cage elevation [44]. The use of a rollator while ambulating allows forward leaning with arm support, thereby decreasing dyspnoea and improving exercise capacity, at least in patients with COPD [68, 69].

### Exercise and physical activity

Exercise intolerance is a hallmark of patients with lung diseases [70]. Exertional dyspnoea and fatigue, or a combination of both, are reported as factors limiting exercise capacity in this population [70]. While dyspnoea is related to the increased central inspiratory neural drive due to the increased work of breathing and ventilatory inefficiency caused by defective gas exchange, parenchyma destruction and dynamic hyperinflation, peripheral muscle fatigue is accompanied by peripheral muscle dysfunction, poor oxidative function, and physical inactivity and sedentarism [70]. Exercise training has long been recognised as a cornerstone of pulmonary rehabilitation programmes [70]. It is known to improve exercise capacity and quality of life in several respiratory diseases independently of disease severity; whether exercise training is associated with enhanced survival remains to be confirmed [71, 72].

In most countries, respiratory physiotherapists are considered members of the core interdisciplinary team within the framework of pulmonary rehabilitation [73]. They typically have a key role in evaluating muscle function and exercise tolerance, prescription and supervision of exercise training and patient coaching to adopt a more active lifestyle in the longer term. They generally are the healthcare providers with the most frequent and close patient contacts (typically two to three times per week) and have an important role in signalling the need for support from other healthcare providers in individual patients.

Current recommendations for exercise training prescription include high-intensity endurance exercise (*i.e.*  $\geq 60\%$  maximal exercise capacity) from three to five times per week, for at least 8 weeks, and resistance training recommendation of one to three sets of eight to 12 repetitions, 2 to 3 days per week, with initial loads of at least 60% of the one-repetition maximum test. Alternatively, a load that evoked fatigue after eight to 12 repetitions can also be used [70]. Exercise training should combine endurance and strengthening exercises for upper and lower limbs [70]. The programme's endurance component should last at least 20 min per session and can be performed in a continuous or interval method [70]. The most functional muscle groups should be targeted for the strengthening exercises [70].

In recent years, interventions aiming to increase physical activity in daily life (PADL), such as physical activity coaching, have been more widely adopted by respiratory physiotherapists [74]. PADL in patients with respiratory diseases is generally low and known to be associated with morbidity and mortality [75]. PADL guidelines recommended goals are at least 150 min per week of activities of moderate intensity (*i.e.*  $\geq 3$  metabolic equivalents (METs)) or 75 min of vigorous intensity (*i.e.*  $> 5$  METs) aerobic activity, or a daily amount of 7000–10 000 steps (table 2) [75–77]. Patients with lung diseases are usually unable to achieve this recommendation [75]. In fact, for an important percentage of patients with severe respiratory diseases, 3 METs exceed their maximum exercise capacity [78]. Recently, more focus has been given to decreasing sedentary behavior and increasing time spent doing light intensity activities (1.5–3 METs), which are also associated with health outcomes [75]. An increase in light intensity PADL appears to be more attainable than increasing moderate intensity PADL [75].

TABLE 2 Minimum recommended parameters for exercise training and levels of physical activity in daily life (PADL)

|                                                     | Exercise training                                                                                                                                                                                                     | PADL                                                   |
|-----------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------|
| <b>Frequency</b>                                    | 3–5 times per week                                                                                                                                                                                                    | $\geq 3$ –5 days per week                              |
| <b>Intensity</b>                                    | Endurance training: $\geq 60\%$ of maximum exercise capacity or 0–10 Borg scale 4–6<br>Resistance training: $\geq 60\%$ of the one-repetition maximum test or a load that evokes fatigue between 8 and 12 repetitions | $\geq 3$ METs                                          |
| <b>Duration</b>                                     | Endurance training: $\geq 20$ –60 min per session<br>Resistance training: 1 to 3 sets of 8–12 repetitions                                                                                                             | $\geq 150$ min per week (or 7000–10 000 steps per day) |
| METs: metabolic equivalents. Data from [70, 76, 77] |                                                                                                                                                                                                                       |                                                        |

It should be noted that exercise training only elicits small improvements in PADL while PADL coaching interventions have a limited impact on exercise tolerance [70, 75]. Hence, both interventions can complement each other when aiming to achieve and maintain a better health status in patients with lung diseases. More emphasis could be given to training or coaching based on identifying treatable traits, individual patient goals and the position of the intervention within the integrated care trajectory (e.g. optimal timing to start rehabilitation after an acute exacerbation).

#### *Peri-operative physiotherapy in a spontaneous breathing patient*

It is well understood that there are a range of physiological changes that result from the systemic inflammatory burden of surgery and effects of anaesthesia including reductions in lung volumes, impaired gas exchange, and alteration in mucociliary function and diaphragmatic dysfunction [79]. Respiratory physiotherapists play an integral role in managing patients undergoing major abdominal and cardiothoracic surgery, namely post-operative pulmonary complication (PPC) [79].

A PPC is a “pulmonary abnormality that produces identifiable disease or dysfunction that is clinically significant and adversely affects the clinical course of recovery” [80], and is one of the most common post-operative complications [81]. A PPC development can negatively impact patient outcomes, hospital length of stay and survival [82]. How PPCs are defined varies enormously depending on the diagnostic criteria that are utilised. Within physiotherapy studies, the Melbourne Group Scale is a valid tool that has been used in abdominal and thoracic surgery studies to determine PPCs amenable to physiotherapy intervention [83, 84].

Traditionally, physiotherapists were involved in the pre-operative setting assessing PPC risk and providing patient education. However, over the past decade, the pre-operative practice has been minimal, with many institutions not having dedicated physiotherapy input in the pre-operative phase and instead focusing resources on the patient’s post-operative care. This change in practice has largely arisen due to the increasing number of operations within the same day, the adoption of minimally invasive surgical procedures, and perhaps the number of physiotherapists within the services. Nevertheless, recent evidence about patients’ education, including smoking and alcohol cessation, stress and anxiety management and prehabilitation, namely through inspiratory muscle training, breathing exercises, aerobic and resistance training [83, 85–87], have demonstrated that pre-operative physiotherapy can reduce PPCs and other post-operative complications, improve exercise capacity and reduce hospital length of stay in some studies across both abdominal and thoracic surgery populations [85–87]. Prehabilitation appears to be beneficial, particularly in high-risk patients optimising their “fitness” to endure surgery stressors and shorten the post-operative recovery period. However, we still do not know the optimal modality, timing, frequency and type of prehabilitation exercise regimes (e.g. including the role of IMT) required in this clinical condition. This uncertainty, combined with feasibility challenges around the short time-frame between diagnosis and surgery, challenges the development of evidence in this area. The importance of patient education has gained interest, particularly as a result of a landmark randomised controlled trial which demonstrated a single 30-min education session delivered pre-operatively; focusing on slow and deep breathing in the early postoperative phase halved the incidence of PPC in elective abdominal surgery [83]. There is also interest in models such as surgery school which encompass multi-modalities, including education and exercise training, to optimise the patients’ recovery pathway [79]. Unfortunately, most patients do not receive any ongoing dedicated physiotherapy after the immediate post-operative phase.

Post-operatively it is routine practice for physiotherapists to provide early mobilisation and respiratory interventions as part of clinical pathways or programmes, such as Enhanced Recovery After Surgery (ERAS) [88, 89]. Evidence about ERAS’ efficacy is available for some conditions, such as colorectal surgery, and is linked to reduced hospital length of stay and PPCs [89–91]. Nevertheless, stronger evidence is still needed, particularly comparing ERAS programmes with or without physiotherapy-led interventions.

There is emerging evidence that post major surgery patients continue to have significant reductions in physical activity, muscle strength, and mental well-being in the months after hospital discharge [88, 92]. It is likely these patients would benefit from ongoing rehabilitation support, such as through pulmonary rehabilitation type programmes. Therefore, evidence-based pathways to support patients across the continuum from diagnosis to the community settings need to be developed [92]. To achieve this we need to continue to understand patients’ risk profile and determine optimal exercise training parameters and modalities across the continuum.

#### **Physiotherapy and noninvasive ventilation**

##### *Noninvasive ventilation during exercise training*

Noninvasive ventilation (NIV) can reduce dyspnoea and hypercapnia by unloading and assisting the overburdened and less effective inspiratory muscles with inspiratory support [93] and reducing work of

breathing with external positive end-expiratory pressure or continuous positive airway pressure [94–96]. Also, unloading the respiratory muscles may prevent exercise-induced diaphragmatic fatigue and improves leg muscle oxygenation [97, 98]. Thus, the rationale behind NIV use during exercise training is that it will lead to greater improvement in exercise capacity [99]. The majority of research about this topic was conducted in patients with COPD. Although a systematic review demonstrated that NIV might enable exercise to occur at a higher training intensity and result in a greater physiological training effect, it could not show a clear effect on exercise capacity [95, 99]. A systematic review in patients with cystic fibrosis found only one cross-over trial reporting that the distance walked increased significantly with NIV during a single session [100]. This intervention is not common practice, as it requires a ratio of one physiotherapist for each patient. Regarding future research, there is a clear need for randomised clinical trials based on statistical power calculations, optimal NIV protocols (mode/settings) and adequate outcome measures. Future studies also need to go beyond the context of COPD and cystic fibrosis and explore the role of NIV in other obstructive and restrictive diseases.

#### ***NIV and airway clearance/lung expansion techniques***

NIV may be a useful adjunct to airway clearance and lung expansion techniques [100]. NIV is hypothesised to decrease respiratory muscle fatigue and prevent airway closure during prolonged expirations, leading to an increase in effective alveolar ventilation and sputum clearance [100]. Most evidence available to date is based on the acute and chronic management of patients with cystic fibrosis. A systematic review showed that airway clearance might be easier with NIV than without it [100]. Likewise, most patients preferred to use NIV compared to not using it during the airway clearance session [100]. Evidence that NIV increased sputum expectoration was unclear. But this review included only six trials assessing the efficacy of NIV on a single-treatment session. Long-term randomised controlled trials are still needed to clarify the effectiveness of NIV.

Evidence from acute disorders management is scarce. A recent randomised controlled trial involving patients with a collection of fluid in the pleural space demonstrated that the addition of noninvasive positive airway pressure of 15 cmH<sub>2</sub>O to mobilisation and respiratory techniques decreased the duration of thoracic drainage, length of hospital stay, pulmonary complications, antibiotic use and treatment costs [101]. In addition, this trial showed that patients tolerated NIV well. Another recent study suggests a reduction in post-operative pulmonary complications with post-operative NIV following high-risk elective upper abdominal surgery [102]. More studies assessing the combined effect of NIV and airway clearance and lung expansion techniques are critical before its widespread use.

#### **Physiotherapy in the ICU**

The field of intensive care medicine has rapidly evolved over the past 60 years since the first ICUs were established in the late 1950s. Today the majority (>90%) of patients will survive this initial life-threatening illness. However, survival comes at a significant cost [103]. Muscle wasting occurs early and rapidly, with up to 30% lost within the first week of an ICU admission [104]. Half of the patients may develop ICU-acquired weakness due to their critical illness, impacting on their functional ability to stand and walk [105]. In 2011 the term “post intensive care syndrome” was adopted to reflect the significant ongoing impairments in physical, cognitive and mental ability in the years post-hospital discharge [103]. These impairments negatively impact participation in family and societal roles, including returning to work [106]. Knowledge of the long-term consequences of ICU survivorship has driven interest in rehabilitation interventions to minimise muscle weakness and post-intensive care syndrome.

Physiotherapists are critical members of the inter-professional ICU team who have expertise in multi-system assessment and management of intubated and spontaneously breathing patients [105]. Traditionally, the mainstay of physiotherapy management was focused on preventing and managing respiratory complications such as atelectasis, sputum retention, and facilitation of ventilatory weaning and/or prevention of reintubation [79]. There is growing evidence to suggest that active mobilisation and rehabilitation may improve muscle strength, functional independence and reduce delirium, particularly if introduced within the first few days of an ICU admission [107]. There is also compelling evidence emerging for IMT to strengthen inspiratory muscles and accelerate weaning in ventilated ICU patients [108].

Despite the potential benefits of early mobility, implementation is challenging due to a lack of resources and safety concerns [109]. A comprehensive systematic review has identified low adverse/safety events associated with mobilisation, with the majority being transient changes in cardiovascular and respiratory systems [110]. Expert recommendations have been developed to guide safety criteria for active mobilisation of mechanically ventilated adult patients considering the differing demands of exercise in and out of bed [111].

The delivery of early mobility requires interprofessional communication and teamwork. The Clinical Practice Guidelines for the Prevention and Management of Pain, Agitation/Sedation, Delirium, Immobility, and Sleep

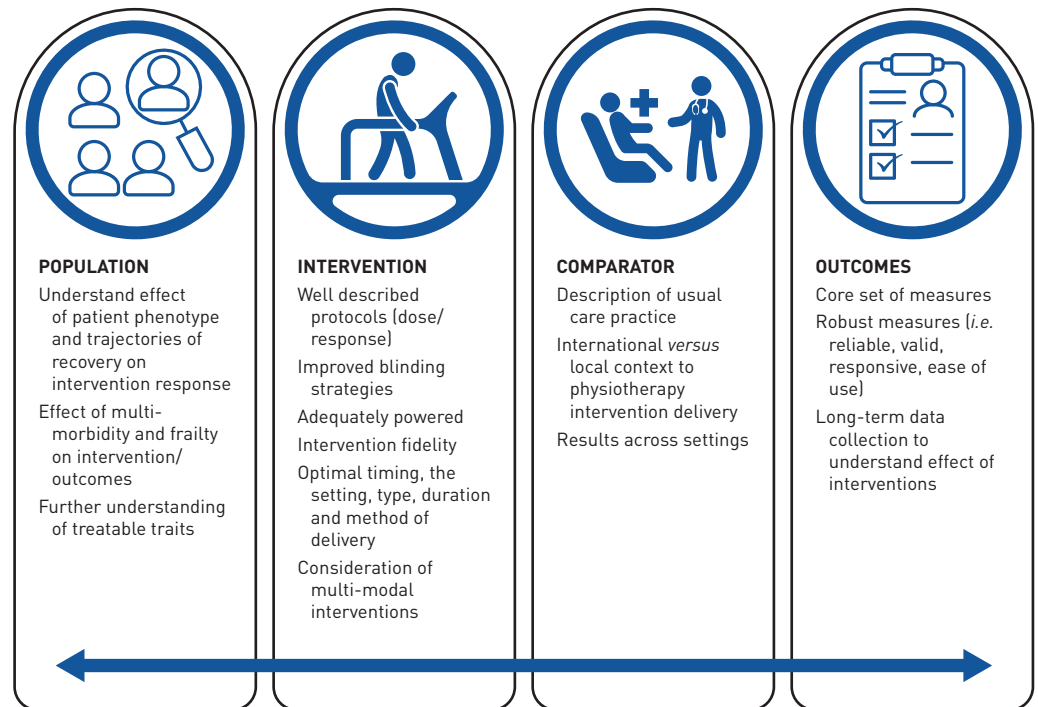


FIGURE 1 Future directions in respiratory physiotherapy.

Disruption in Adults Patients in the ICU (PADIS) provides recommendations on managing pain, agitation, delirium, immobility and sleep. These are recognised as key modifiable factors that may impact the development of muscle weakness and long-term mental, cognitive and physical impairments [112]. To assist with implementing these recommendations into practice, an evidence-based interprofessional team management strategy known as the ABCDEF bundle with “E” reflecting early mobility has been recommended [113]. However, despite increased interest and referral for physiotherapy, there is often insufficient staffing and access to dedicated mobility teams, particularly in resource-limited settings.

### Future research directions

This work demonstrates the strong contribution of physiotherapists and their specific interventions in the integrated care of patients with respiratory diseases. With the growth of respiratory physiotherapy research and physiotherapist specialty training in recent years, a boost in evidence-based practice was seen. Currently, respiratory physiotherapists are more used to support their clinical decision-making on their professional practice expertise, the best available evidence and on patients’ preferences. As we have shown throughout the different sections, there are several unanswered questions about the effectiveness of our interventions that we should pursue in the coming years (figure 1). To do that properly, we should learn from current evidence gaps and conduct studies with high methodological rigor. Randomised control trials are needed to demonstrate the effectiveness of our interventions. These studies still need to include larger samples based on size estimation, optimal and well-described protocols (dose/response), improved blinding strategies, responsive outcome measures (compliance), and long-term data. However, well-designed observational studies to assess our intervention feasibility across distinct settings and acceptability by distinct groups of patients are also required. Besides, evidence needs to go beyond cystic fibrosis, COPD, bronchiectasis, critical patients and also address less-studied groups of respiratory patients.

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