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Cornerstone review

## Exercise in cancer care for people with lung cancer: A narrative synthesis

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## ABSTRACT

**Objectives:** Lung cancer is the second most common cancer diagnosed worldwide, resulting in significant physical and psychological consequences. In this narrative review, we explore the role of exercise as an adjunct therapy to counteract health issues experienced by people before, during and after treatment for lung cancer, and offer recommendations for exercise prescription and future research.

**Design:** Narrative cornerstone review.

**Methods:** A narrative review was conducted to explore the role of exercise in cancer care for people diagnosed with lung cancer.

**Results:** Improvements in fitness, strength and quality of life have been demonstrated in people with lung cancer following participation in exercise programmes before, during and post treatment. Whilst combined aerobic (50–100 % heart rate maximum) and resistance (50–85 % of 1 repetition maximum) training, 2–5 times per week across the cancer continuum is typically prescribed, few people with lung cancer currently access exercise services. 'Optimal' exercise prescription is unclear, although is likely individual-specific. The immediate priority is to identify a tolerable starting exercise dosage, with the side effects of lung cancer and its treatment on the respiratory system, particularly shortness of breath (dyspnoea), likely driving the initial maximum threshold for session mode, duration and intensity. To date, exercise safety for people with lung cancer has been poorly evaluated and reported – few trials report it, but those that do report small numbers of serious adverse events.

**Conclusions:** Recommendations for health professionals prescribing exercise therapy to people with lung cancer are provided, with consideration of the strengths and limitations of the current evidence base.

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## 1. Background

Lung cancer is a leading cause of cancer-related morbidity and mortality worldwide, with substantial impact on individuals and the public health system.<sup>1,2</sup> The direct effects of lung cancer combined with the

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indirect effects of cancer treatment can cumulatively lead to reductions in exercise capacity and quality of life. There exists epidemiological and clinical trial evidence which supports exercise as a potential adjunct therapy for people with lung cancer. Interventions to support patients to improve their health are clearly warranted and should be encouraged.<sup>3,4</sup> Emerging evidence is reporting that specifically higher pre-diagnosis and post-diagnosis levels of physical activity are associated with improved survival outcomes in lung cancer.<sup>5,6</sup> Lung cancer and its associated treatments (e.g. surgery, chemotherapy, radiotherapy) have a direct impact on the anatomy and function of the respiratory system,<sup>5</sup> including changes in respiratory muscles, lung capacity, and gas exchange processes. These adverse sequelae also affect exercise capacity and the ability to partake in activities of daily living. To date the majority of exercise research has been focused on breast, prostate, colorectal and haematological cancers. Evidence is emerging on the benefits of physical activity and exercise (which is categorised as a subgroup of physical activity) in lung cancer; however, it is not as well understood.<sup>7</sup>

People with lung cancer experience unique, disease-specific supportive care needs due to the nature of their condition.<sup>8</sup> Common side effects of the disease include cough, shortness of breath (dyspnoea), chest pain, fatigue, weight loss, haemoptysis (coughing up blood), and pneumonia.<sup>9</sup> There is also high prevalence of comorbidities, such as chronic obstructive pulmonary disease, among people with lung cancer.<sup>10</sup> These comorbidities can significantly impact the treatment process and overall well-being of patients.<sup>11</sup> The side effects associated with lung cancer treatment can be challenging for patients. These side effects can vary depending on the specific treatment regimen. It is important to note that whilst some side effects may be common among different types of cancer treatments, people with lung cancer may experience side effects unique to their specific treatment plan such as anxiety and depression (which may relate to the stigma of diagnosis), radiation damage to the lungs, long-term neuropathy, bone metastases and hearing loss.<sup>12</sup> Treatments including radiotherapy, chemotherapy, targeted therapy, and immunotherapy can all contribute to different side effects experienced by people with lung cancer.<sup>13</sup> Additionally, the stigma commonly associated with a lung cancer diagnosis can impact outcomes.<sup>14</sup> This stigma, often rooted in the misconception that lung cancer is solely caused by smoking, can lead to feelings of shame, guilt, and isolation among patients. These emotions can deter individuals from seeking timely medical care, adhering to treatment plans, and engaging in supportive care services. Consequently, delayed diagnosis, suboptimal treatment adherence, and reduced access to psychosocial support can collectively contribute to poorer outcomes for individuals with lung cancer.<sup>14</sup>

There is a clear need for the provision of supportive care that has potential to improve health outcomes for this unique subgroup of the broader cancer population, facing distinct challenges that significantly impact their physical and functional well-being.<sup>3,4</sup> These challenges stem from the complex interplay of the disease itself, treatment-related side effects, and psychosocial factors. Lung cancer often directly affects the respiratory and cardiovascular systems, leading to reduced lung function, decreased exercise capacity, and increased breathlessness. These physiological impairments can make engaging in physical activity more difficult and contribute to a downward spiral of deconditioning and functional decline. Lung cancer treatments, such as surgery, chemotherapy, and radiation therapy, can exacerbate these existing impairments and introduce additional side effects like fatigue, muscle wasting, and peripheral neuropathy. These treatment-related toxicities can further impede patients' ability to participate in physical activity, contributing to a cycle of inactivity and worsening health outcomes. People with lung cancer can also experience feelings of anxiety, depression, and isolation that can create barriers to engaging in physical activity, further complicating the rehabilitation process.

People with lung cancer often have a high number of unmet needs.<sup>15</sup> These needs can be physical, emotional, social, intellectual, or spiritual in nature.<sup>16</sup> Physical and psychological challenges that adversely

influence quality of life are often reported and can include fatigue, anxiety, depression, muscle wasting, and reduced physical function.<sup>5</sup> Uniquely people with lung cancer also experience pain, breathlessness, and emotional and psychological distress. Difficulties arise and impact coping with the impact of diagnosis and its treatments on daily life.<sup>16</sup> Supportive care, which focuses on improving quality of life and providing support throughout the illness, plays a crucial role in addressing these needs.<sup>17,18</sup> It is important for healthcare professionals, including clinical exercise physiologists and physical therapists recognise and address these specific supportive care needs to improve outcomes for people with lung cancer.

Published literature suggests that exercise interventions if tailored to the specific needs of individuals, could have a positive impact on various aspects of their health.<sup>19–23</sup> However, it is agreed that the most effective type and dosage of exercise for patients with lung cancer, consistent with many other cancer types, remain an area of ongoing research (Table 1). The optimal exercise prescription for patients with lung cancer is currently not known, which makes it challenging when developing personalised exercise interventions. Given this, it is important to use what we know across other cohorts when prescribing exercise. Factors such as the cancer stage, treatment modalities, and individual characteristics must be considered when designing and delivering exercise programmes for people with cancer.<sup>24,25</sup> Moreover, different exercise modes, including cardiorespiratory exercise, resistance and respiratory muscle training and mindfulness exercises (e.g. Yoga), as well as at different intensities (e.g. light, moderate, -to-vigorous, vigorous), may offer distinct advantages in improving health.<sup>26</sup> The advantages of one mode over another needs to be considered in this context, and should be tailored to individual preferences, needs and capabilities.

The field of exercise for people with lung cancer is still in its infancy and exercise programmes for people with lung cancer are uncommon in clinical practice. This review aims to provide a comprehensive overview of existing evidence on the role of different exercise modes and dosages in the care of individuals diagnosed with lung cancer. We aim to also provide clinical updates for patients, healthcare professionals, and researchers on the potential benefits of exercise interventions for individuals diagnosed with lung cancer to inform future models of care. Finally, we will discuss the challenges and future directions in this field, emphasising the need for further research to strive towards embedding exercise into lung cancer care by optimising exercise prescription as part of the interdisciplinary approach to care, which will likely improve the health outcomes and quality and potentially longevity of life in this population group.

## 2. Effects of exercise in lung cancer

Exercise aims to improve the patient's physical condition, including strength, cardiovascular fitness, flexibility, and endurance. This can help patients better tolerate the physical demands of diagnosis, surgery, treatment and recovery. Exercise improves lung function, which is a common concern in patients who have undergone lung resections.<sup>27–29</sup> In particular breathing exercises (including respiratory muscle training) have emerged as a valuable adjunctive therapy in the care of patients with lung cancer.<sup>30</sup> The benefits of incorporating breathing exercises and respiratory muscle training into the management of lung cancer are multifaceted. Firstly, this type of training has been shown to enhance respiratory function, improving lung capacity and oxygen exchange, which can be particularly beneficial for patients experiencing dyspnoea or compromised lung function due to diagnosis or treatments.<sup>31</sup> Additionally, respiratory training has been shown to lead to a reduction in anxiety and depression, common among patients with lung cancer. This occurs by providing a sense of control and empowerment over their breathing and overall well-being. Furthermore, it plays a pivotal role in prehabilitation, helping patients optimise physical conditioning prior to surgery, leading to reduced post-operative pulmonary complications

**Table 1**Current cardiorespiratory and resistance exercise prescription recommendations for people diagnosed with lung cancer (operable & inoperable).<sup>20,40,51,56,58,94–97</sup>

Timing	Type	Delivery	Length	Frequency (days/week)	Setting	Volume	Intensity	Outcomes
Preoperative	Cardiorespiratory exercise (n = 74) <sup>41</sup>	Supervised, setting (individual and group)	25 days	3	Hospital	High-intensity interval training consisting of bouts of 15 s interspersed by 15 s of passive resting for 10 min	100 % of peak cardiorespiratory power	↑ Cardiorespiratory fitness ↑ Lung function ↓ Dyspnoea ↑ Physical function
	Resistance exercise	Unknown		Unknown		Unknown	Unknown	Unknown
Postoperative	Combined exercise (n = 18) <sup>52</sup>	Supervised (individual and group)	3 weeks	3–5	Hospital	Cardiorespiratory: 15–45 min Resistance: 3 sets of 12 repetitions	Cardiorespiratory: Unknown Resistance: 60–70 % of 1-RM	↑ Cardiorespiratory fitness
	Cardiorespiratory exercise (n = 32) <sup>95</sup>	Supervised	6 weeks	Unknown	Hospital	60 min	50–70 % of patient's exercise capacity	↑ Physical function ↑ Cardiorespiratory fitness
	Resistance exercise	Unknown		Unknown		Unknown	Unknown	Unknown
	Combined exercise (n = 221) <sup>96</sup>	Supervised	12 weeks	2	Hospital	Cardiorespiratory: High-intensity interval training consisting of bouts of 1 min interspersed by 1 min of passive resting for 25 min Resistance: 3 sets of 8–12 repetitions	Cardiorespiratory: 85 %–100 % of HR max Resistance: 60–80 % of 1-RM	↓ Fatigue
During treatment (all types)	HIIT <sup>97</sup>	Supervised	25 days	3	Hospital	Cardiorespiratory: High-intensity interval training	Two 10-minute series of 15-second sprint intervals (at 80 %–100 % peak WR) interspersed by 15-second pauses and a 4-minute rest between the two series	↑ Cardiorespiratory fitness
	Cardiorespiratory exercise <sup>98</sup>	Unsupervised	8 weeks	Unknown	Home	Unknown	Unknown	↑ HRQoL (Functional Assessment of Cancer Therapy–Lung & symptom severity (MD Anderson Symptom Inventory–Lung Cancer))
	Resistance exercise <sup>59</sup>	Unknown	12 weeks	Unknown	Hospital	Unknown	Unknown	↓ Anxiety and depression ↑ Muscle strength
	Combined exercise (n = 26) <sup>57</sup>	Supervised & unsupervised	4 weeks	5	Hospital	Cardiorespiratory: 20–30 min Resistance: Unknown	Cardiorespiratory: 30–80 % of peak work rate Resistance: 40–70 % of 1-RM	↑ Physical function ↑ Cardiorespiratory fitness
Post-treatment	Cardiorespiratory exercise (n = 24) <sup>20</sup>	Supervised	16 weeks	3	Hospital	20–60 min	55–95 % of ventilatory thresholds	↑ Cardiorespiratory fitness
	Resistance exercise (n = 23) <sup>20</sup>	Supervised		3		3 sets of 6–18 repetitions	50–85 % of 1-RM	↑ Muscle strength
	Combined exercise (n = 20) <sup>20</sup>	Supervised	16 weeks	3	Hospital	Cardiorespiratory: 20–60 min Resistance: 3 sets of 6–18 repetitions	Cardiorespiratory: 55–95 % of ventilatory thresholds Resistance: 50–85 % of 1-RM	↑ Cardiorespiratory fitness ↑ Muscle strength ↑ Lean mass ↓ Body fat

1 repetition maximum (1-RM), health related quality of life (HRQoL), peak work rate (peak WR), and high intensity interval training (HIIT).

and improved postoperative outcomes.<sup>32</sup> Importantly, respiratory training may enhance the tolerance of cancer treatments such as chemotherapy and radiation therapy, reducing the risk of treatment discontinuation due to respiratory-related side effects.<sup>6</sup> Regular cardiorespiratory exercise has been shown to enhance the heart's ability to pump blood efficiently, lower blood pressure, reduce cardiovascular risk factors, enhance blood flow, and improve heart function, all lowering the risk of cardiovascular complications in lung cancer, including a reduction in mortality.<sup>33</sup> Overall, the current literature underscores the substantial advantages of integrating respiratory training into the care plan for patients with lung cancer, offering both palliative relief and opportunities to enhance the effectiveness of therapeutic interventions across the cancer care trajectory.

### 3. Preoperative exercise in lung cancer

Preoperative patients will present with different fitness levels and comorbidities before surgery, which will affect their tolerance to different exercise types and dosage.<sup>23,34,35</sup> Patient input into exercise selection is crucial for the uptake of the programme during this phase.<sup>36</sup> Healthcare providers should assess each patient's individual circumstances and fitness level to determine the appropriateness of an exercise programme to assist with surgery success and recovery from surgery as per the current guidelines. To provide the best possible care, patients work with the team of surgeons, medical oncologists, exercise physiologists, nutritionists, dietitians, and other healthcare professionals. This team creates a personalised preoperative plan tailored to the patient's needs.<sup>37–39</sup>

Preoperative exercise offers a multitude of benefits for lung cancer patients. Studies have shown it can significantly improve quality of life and cardiorespiratory fitness.<sup>40</sup> Additionally, the American Society of Clinical Oncology recommends exercise to reduce hospital stays and complications after surgery. Research suggests a clear advantage for patients who participate in holistic preoperative care programmes that include exercise.<sup>35,41</sup> These programmes can lead to reduced anxiety, depression, and fatigue, whilst also boosting mood and overall well-being.<sup>42</sup> More importantly, preoperative exercise programmes may be linked to a significant decrease in postoperative complications.<sup>43–45</sup> This translates to shorter hospital stays<sup>21,43,46,47</sup> and faster recovery,<sup>28,48,49</sup> potentially reducing healthcare costs and improving the patient's experience.<sup>21,50</sup> Interestingly, shorter and more intensive programmes (5 sessions/week for 3 weeks) seem to be more effective than longer programmes with lower frequency (3 sessions/week for 5 weeks), although further research is needed to understand the reasons behind this.<sup>51</sup>

### 4. Postoperative exercise in lung cancer

Postoperative exercise is instrumental in mitigating the potential functional impairments from lifesaving surgical procedures, particularly when lung tissue has been excised. Equally as important is the enhanced efficiency of the skeletal muscle to use oxygen for energy production achieved with exercise. Muscle size and strength are also critical because relative intensity of tasks is lower, reducing load on the cardiovascular and pulmonary systems. Furthermore, exercise post-surgery has the capacity to reduce the incidence of postoperative complications, such as pneumonia and atelectasis (partial collapse or incomplete inflation of the lung), attenuating common morbidity associated with lung cancer surgery.<sup>21</sup>

Postoperative exercise emerges as a therapeutic path that addresses the often-debilitating psychological distress experienced by patients with lung cancer, which may be characterised by anxiety and depression.<sup>52–55</sup> It is imperative to adopt an individualised approach that tailors exercise programmes to the specific goal, as well as the patient's overall health and fitness profile. To improve safety and effective implementation of these programmes, structured rehabilitation initiatives, commonly offered by cancer centres and supervised by specialised healthcare professionals (such as clinical exercise

physiologists) with expertise in exercise oncology, play an essential role in recovery and improving psychosocial outcomes.

A body of evidence emphasises the potential for less hospital visits among patients who actively participated in postoperative exercise programmes, fostering accelerated reintegration back into their daily routines.<sup>6,50,56,57</sup> Beyond these benefits, postoperative exercise has been identified as a potent safeguard against the depletion of muscle mass that is frequently observed in the aftermath of lung cancer surgery.<sup>56,58</sup> By participating in resistance training programmes, patients experience less muscle wasting, and a greater preservation of functional capacity compared to those who do not. Additionally, exercise has been shown to improve pain management, aiding in pain control and facilitating the restoration of mobility.<sup>22,23,59</sup>

Encouragingly, postoperative exercise can also be used well past the immediate post-surgery period, with benefits emerging displaying improved long-term physical health and psychological well-being.<sup>48,58,60</sup> However, adverse event monitoring and safety precautions are essential throughout the delivery of exercise, particularly during the early postoperative phase when patients may be more susceptible to complications.<sup>2,23</sup> The precise timing of exercise initiation following surgery needs individual consideration, a decision best made in consultation with the surgical and medical teams and the individual as evidence is emerging in this space. It is crucial for healthcare providers to remain up to date on the most recent medical literature and guidelines, ensuring that exercise interventions prescribed in clinical care align with the latest evidence-based practices.<sup>61</sup>

### 5. Exercise during treatment in lung cancer

Exercise can play a vital role in promoting cardioprotective effects in patients with lung cancer.<sup>33,62,63</sup> especially during treatment. Integrating exercise into the treatment could contribute to better cardiovascular and overall health outcomes and enhance the well-being, length and quality of life of individuals diagnosed with lung cancer. Chemotherapy can have various negative effects on the heart, including in people diagnosed with lung cancer.<sup>64–66</sup> These effects may vary depending on the specific chemotherapy drugs used, the dosage, and the individual patients' overall health. Some systemic therapies for lung cancer risk cardiotoxicity e.g., cisplatin based, or targeted drugs against the vascular endothelial growth factor such as Bevacizumab, as well as immune therapies can have a negative impact.

Patients with lung cancer who engage in regular exercise during treatment may experience less fatigue, nausea, and discomfort during treatment.<sup>67–69</sup> Exercise during treatment can also help patients maintain muscle mass and function, which is crucial for overall health and quality of life.<sup>6,70</sup> Importantly, exercise can have a positive impact on the psychological well-being of patients with lung cancer because it can reduce anxiety, depression, and stress, providing emotional support during treatment.<sup>22,71,72</sup> Encouraging patients diagnosed with lung cancer to maintain an active lifestyle during treatment can help prevent disease recurrence and promote long-term health.<sup>6,53,73</sup> Some studies have suggested that incorporating exercise into the treatment plan for patients with lung cancer can help improve tolerance to various treatments, including chemotherapy and radiotherapy.<sup>34,74</sup> This may result in fewer interruptions and higher treatment adherence.<sup>58,75,76</sup>

### 6. Exercise for advanced disease in lung cancer

Patients with advanced-stage lung cancer who may not be candidates for curative treatments can benefit by participating in exercise, playing an important role when their clinical management begins to shift towards palliative care.<sup>17,35,56,58,77,78</sup> Exercise could help manage cancer-related symptoms such as fatigue, breathlessness, pain, and muscle weakness, symptoms commonly experienced later in the disease progression.<sup>17,78</sup> Tailored exercise programmes have been shown to improve functional capacity and alleviate symptoms.



Regular exercise has been reported to enhance the overall quality of life for individuals with advanced-stage lung cancer.<sup>58,72</sup> It provides a sense of accomplishment and normalcy amid the challenges of the disease. Exercise helps preserve physical function and independence, allowing patients to continue performing daily activities and maintaining a level of autonomy for as long as they can. It also reduces anxiety and depression, improves mood, and provides a sense of control and empowerment. Group exercise should be considered for people with advanced-stage lung cancer, when feasible, as it can provide social interaction and support, which can be particularly valuable for these individuals with advanced disease. At this stage of lung cancer, individuals may find breathing exercises and relaxation techniques useful in helping manage breathlessness, pain and anxiety which is associated with the disease.<sup>17</sup>

## 7. Exercise for managing cachexia and bone metastases in lung cancer

It is essential for patients with lung cancer and their healthcare providers to screen and assess for cachexia early to be able to mitigate the impact on treatment and quality of life.<sup>79,80</sup> There is currently a lack of standardised approaches used to diagnose cachexia. Lung cancer and its treatments can lead to cachexia, which includes skeletal muscle wasting.<sup>81,82</sup> Cachexia affects up to 80 % of individuals with advanced-stage cancer.<sup>82,83</sup> It is more frequently observed in small cell lung cancer (SCLC) and less commonly NSCLC.<sup>82,83</sup> The exact mechanisms of developing cachexia in lung cancer are not fully understood, but it is believed to result from a complex interplay of factors such as the presence of tumour-derived factors, systemic inflammation, and metabolic alterations driven by the cancer.<sup>79,84</sup> Given that many patients with lung cancer can experience cancer cachexia with symptoms such as unexplained weight loss, muscle weakness, fatigue, loss of appetite, and overall decline in physical function, it has been shown that resistance exercise in combination with other treatments could be an important intervention to reverse or minimise the impact of these factors.<sup>79,80,85</sup>

Managing cachexia in patients with lung cancer is complex and should involve a multidisciplinary approach. Strategies may include nutritional support, appetite stimulants, resistance exercise, and interventions aimed at reducing systemic inflammation.<sup>86</sup> Cardiorespiratory exercise should be limited in volume as this may increase the energy deficit, accelerating weight loss and might also interfere with the anabolic effects of resistance training.<sup>87</sup> In some severe cases, medications like corticosteroids may be prescribed.<sup>88,89</sup> Patients with lung cancer with cachexia may also experience psychological distress, therefore psychosocial support, including counselling and support groups, could potentially help address the emotional and mental health effects of cachexia.

Approximately 20–30 % of lung cancer patients are diagnosed with bone metastases, and an additional 35–40 % develop them during the course of their illness.<sup>90</sup> The presence of bony metastases in people diagnosed with certain types of lung cancer is a predictor of poor overall survival.<sup>91</sup> Exercise may play an important part in the management of individuals with bony metastases. Exercise has been shown to be safe and feasible for individuals with lung cancer when it included an element of supervision with exercise instruction.<sup>92</sup> Historically, health professionals have hesitated to prescribe exercise for people with bone metastases due to concerns about potential complications, such as fractures and spinal compression.<sup>93</sup> However, emerging evidence in other cancer populations suggests that exercise can be safe and well-tolerated for individuals with bone metastases, contributing to the preservation of physical function.<sup>92</sup> To ensure safety, exercise programmes must be meticulously designed, considering the specific site of metastases, and collaboration with specialised health professionals, such as oncology physiotherapists or exercise physiologists, is recommended to tailor individualised exercise programmes for people diagnosed with lung cancer who have bone metastases.

## 8. Current exercise research recommendations in lung cancer

This review demonstrates that research in exercise and lung cancer is growing (Supplementary Table 1), and there is high heterogeneity in the exercise interventions in the current body of evidence and a lack of lung cancer specific exercise guidelines. Specific exercise recommendations for individuals diagnosed with lung cancer have recently been developing, with recommendations varying based on the individual's specific condition, treatment stage, and overall health.<sup>23</sup> Generally, the ACSM recommends that individuals with cancer, including lung cancer, aim for moderate-intensity cardiorespiratory exercise (30 min 3 × weekly during treatment, 150–300 min per week post treatment), typically at an intensity between 50 % and 70 % of maximum heart rate.<sup>98,99</sup> Common cardiorespiratory exercise recommendations include brisk walking, cycling and swimming. These activities are often well-tolerated and can help improve cardiovascular fitness.<sup>2</sup>

It is well established in both healthy and clinical populations that the acute and chronic effects of exercise are highly specific to the mode, volume and intensity of the exercise performed.<sup>2</sup> Cardiorespiratory exercise training enhances cardiac, circulatory and pulmonary function as well as the efficiency of skeletal muscles to use oxygen for energy production.<sup>100</sup> Resistance training increases capacity and efficiency of the neuromuscular system resulting in increased strength, power and functional ability usually underpinned by increased muscle mass.<sup>101</sup> The ACSM recommends performing resistance exercise in 2–3 sets of 8–12 repetitions for each major muscle group.<sup>102</sup> Resistance training exercises can involve weight machines, free weights, or resistance bands. Resistance exercise is particularly important to maintain or build muscle mass in patients with cancer. It is also suggested that flexibility and balance exercises be incorporated into the patient's routine as it can help improve overall physical function and reduce the risk of falls, which can be an issue for older or mobility-limited patients with lung cancer.<sup>2,98</sup> due to physiological changes experienced and their increased risk of cachexia.

Given the debilitating effects of lung cancer, exercise programmes should be carefully individualised and developed in consultation with healthcare providers who specialise in exercise oncology or rehabilitation for people with lung cancer.<sup>2,103</sup> The type and dosage of exercise should be tailored to the patient's specific diagnosis, treatment plan, and any physical limitations or the side effects that people with lung cancer are experiencing.<sup>2,23</sup> It is suggested that exercise programmes incorporate the principle of progressive overload,<sup>104</sup> where the dosage and intensity or resistance of the exercises are gradually increased over time. Depending on the individual's current condition and treatment status, exercise programmes may benefit from close monitoring and supervision by healthcare professionals or trained exercise specialists.<sup>2,23</sup> This is especially important during active treatment phases. Exercise programmes should be adapted to address symptoms and morbidities because individuals with lung cancer may experience various debilitating symptoms and side effects, such as fatigue, breathlessness, and muscle weakness as well as escalation of other chronic diseases such as sarcopenia, osteoporosis, cachexia, and cardiovascular disease.<sup>68</sup>

Patients with lung cancer, particularly those receiving certain treatments, are more susceptible to infections and other complications.<sup>105</sup> Adequate infection control measures and precautions should be taken in exercise environments to ensure the safety of the patient. Exercise programmes have many psychosocial benefits, including improved mood and reduced anxiety and depression.<sup>77</sup> Incorporating psychosocial support elements into exercise routines, such as group classes or counselling, may be a beneficial approach for best outcomes for these patients.<sup>23,106</sup> It is important to note that individual factors, such as the stage of cancer, overall health, and treatment specifics, can and should be taken into consideration and may influence exercise prescription, implementation, and monitoring (Supplementary Table 1).

## 9. Interdisciplinary care in lung cancer

A successful interdisciplinary patient-centred approach to the care of people with lung cancer involves the patient, carer, oncologists, clinical exercise physiologists, dieticians, psychologists, and physical therapists/physiotherapists. The inclusion of exercise in the care of this patient population is key and could improve outcomes.<sup>97,107</sup> A coordinated approach ensures that exercise is integrated into the patient's overall treatment plan.

Exercise for lung cancer should be integrated into a patient's routine in a way that minimises fatigue and discomfort and fits in with the individual's needs for that day.<sup>17</sup> Incorporating behaviour change techniques into exercise sessions, such as personalised goal setting, action planning and identification of exercise enablers and barriers is key given that many people with lung cancer will not have exercised or been physically active prior to their diagnosis.<sup>108</sup> Integrating the team of experts working with the individual is key. For example, in advanced disease exercise plans should be coordinated with the palliative care team, including physicians, nurses, and other specialists, to ensure that they align with overall palliative care goals and priorities of the patient. Assessment of the patient's physical function, symptoms, and overall well-being could help with adjusting the exercise plan as needed to address changing needs and capabilities of patients, without being burdensome. Table 2 has been developed to assist clinicians in identifying specific clinical exercise considerations for people with lung cancer.

When exercise programmes are provided in the setting of interdisciplinary care, that includes psychosocial support, it can assist with reducing anxiety, depression, and stress in patients with lung cancer.<sup>39</sup> Group-based exercise sessions may also foster a sense of community and support which can help improve psychosocial functioning, highlighting the potential importance of connecting with family and friends.<sup>109</sup> Effective incorporation of exercise into interdisciplinary care should be tailored to each patient's specific needs and capabilities as recommended in the exercise guidelines for people diagnosed with cancer.<sup>2,98,103</sup> Healthcare providers should consider the patient's choices, access, stage of cancer, treatment plan, comorbidities, and fitness level when prescribing exercise.<sup>2</sup>

## 10. Adherence and barriers to exercise in lung cancer

Exercise adherence can be challenging for individuals with lung cancer due to the physical and emotional impact of the disease and treatments.<sup>110–112</sup> A lack of financial means to access a prescribed exercise programme beyond Medicare (in Australia) or funded sessions could also cause a person not to exercise. It is important that the treating team supports patients to improve exercise adherence, and respiratory assessment should be carried out to prioritise and optimise sessions for those with COPD prior to exercise and also any cardiovascular risk excluded and managed if a co-existing long-term tobacco history is reported/known. Healthcare providers should educate patients about the benefits of exercise and the role in managing cancer-related symptoms and side effects. Patients should be informed about the specific exercise recommendations tailored to their individual goals, condition and treatment stage. Establishing achievable exercise goals is essential. Goals should be realistic and adapted to the patient's current needs and physical condition.<sup>97,113</sup> Setting both short-term and long-term goals could provide motivation and a sense of accomplishment for patients. Healthcare providers can provide ongoing and regular motivation and encouragement to patients to adhere to their exercise routines.

Exercise plans should be adapted to support different treatment phases. For example, during active treatment, the intensity and type of exercise may need to be adjusted to account for fatigue or treatment side effects. Encouraging patients to engage in recommended activities that they enjoy can make exercise more enjoyable and sustainable in

**Table 2**

Clinical exercise considerations.

Consideration	Stakeholder
Moderate to vigorous-intensity cardiorespiratory exercise and resistance training are recommended (detailed in Table 1).	Exercise professionals
Exercise programmes should incorporate the principle of progressive overload, where the frequency, dosage and intensity of exercises are gradually increased over time as tolerated by the individual or regressed if necessary due to disease progression or treatment toxicities.	Exercise professionals
A thorough assessment by healthcare providers, including oncologists, clinical exercise physiologists, and physical therapists/physiotherapists, should guide the development of an exercise plan, with the support of the multidisciplinary team to ensure it is adhered to and implemented into care.	Healthcare professionals
Patients with lung cancer may be at increased risk of certain complications, including infections and blood clots. Exercise environments should minimise risk of hazards and be hygienic, especially during active treatment phases. New and worsening symptoms should be reported to the treating clinician.	Healthcare professionals
Depending on the individual's health status, close monitoring and supervision of the exercise programme by clinical exercise physiologists, other trained exercise specialists, or healthcare professionals may be required.	Healthcare professionals
Lung cancer can affect respiratory function, and including breathing exercises (such as inspiratory muscle training) in the programme can help improve lung capacity and manage breathlessness and reduce post-operative pulmonary complications.	Exercise professionals
Exercise can have positive psychosocial benefits, including improved mood and reduced anxiety and depression. Incorporating psychosocial support elements into exercise routines, such as group classes or counselling, may be beneficial for patients with lung cancer.	Exercise professionals
Some patients with lung cancer may be taking medications or having treatments that can affect exercise capacity or interact with exercise acute and chronic effects. It's important to coordinate exercise plans with medication management and understand any side effects that may need to be considered.	Healthcare professionals
It is important to ensure that exercise is safe and appropriate, especially if there are any specific medical concerns. Referral to an accredited exercise physiologist is considered best practice.	Healthcare professionals
Encouraging patients with lung cancer to incorporate physical activity into their daily routines, such as walking and increasing incidental exercise, can be an effective way to promote ongoing activity and reduce sedentary time.	People diagnosed with lung cancer
Ongoing education to healthcare providers and people with lung cancer about the potential benefits of exercise is essential to increase the number of people referred to or who self-refer to exercise programmes.	Researchers
Further economic evaluations of exercise programmes for people with lung cancer are needed. Findings of cost-effectiveness can be used to support business case development to increase the number of available exercise programmes to facilitate the provision of exercise to people with lung cancer as part of routine care.	Researchers

NB: Due to the extensive and significant impact that lung cancer has on a patient's physical condition and overall health there are some considerations developed from this review that clinicians should be mindful of.

the long term. Addressing emotional well-being is crucial, patients should be encouraged to access psychosocial support, including counselling or support groups if needed, and this may help support them to cope with the emotional challenges of lung cancer. Few lung cancer exercise trials report serious adverse events; however, these data are often not adequately reported in the literature. Given the significant proportion of people with lung cancer presenting with advanced disease consideration is needed regarding the presence of any bony metastases. Expert consensus exercise recommendations for people with bony metastases include assessing the risk of potential skeletal complications against the potential benefits of exercise.<sup>98</sup>

## 11. Breathing exercises and inspiratory muscle training (IMT) in lung cancer

Breathing exercises and inspiratory muscle training (IMT), whilst both involving the respiratory system, serve distinct purposes with differing impacts on cardiorespiratory fitness, particularly for individuals with lung cancer. Breathing exercises, such as diaphragmatic breathing and pursed-lip breathing, primarily focus on promoting relaxation, reducing stress, and managing symptoms like anxiety and dyspnoea, which are common in this population. These exercises typically have minimal impact on cardiorespiratory fitness. IMT is a specific form of exercise designed to strengthen the diaphragm and other respiratory muscles. For individuals with lung cancer, IMT can be particularly beneficial by improving breathing efficiency, lung function, exercise tolerance, and potentially enhancing cardiorespiratory fitness. IMT may help reduce dyspnoea and fatigue, common side effects of cancer treatment, and may even improve quality of life for this population.

Inclusion of breathing exercises as part of effective exercise prescription is particularly important in the pre-operative and immediate post-operative treatment phases. In a meta-analysis of randomised controlled trials (RCTs) of pre-operative breathing exercises compared to usual care, the intervention resulted in significantly fewer post-operative pulmonary complications (including pneumonia) and shorter hospital length of stay.<sup>32</sup> In 8 of 10 RCTs the breathing exercise intervention included IMT. Post-operatively IMT has also been demonstrated to improve patient outcomes, including respiratory muscle strength.<sup>94</sup> IMT is simple, easy for patients to perform and involves breathing exercises through a resistance device, such as a Power Breathe. These are commonly performed for 10–20 min, twice daily with the level of resistance increased as the patient progresses.

## 12. Recommendations from this review

Based on the findings of our review, exercise prescription should involve discussion with the patient and their healthcare team and assessment prior to starting an exercise programme, especially if pre-existing cardiovascular, pulmonary, endocrine or neurological conditions are present or if patients are currently undergoing active cancer treatments. The type, dosage and intensity of exercise should be determined in consultation with the medical team and clinical exercise physiologists or physical therapists/physiotherapists and include the input of the multi-disciplinary team. Determining the appropriate exercise intensity is crucial for people with lung cancer and should also be tailored to the individual's characteristics, such as overall health, symptoms experienced, fitness levels and exercise tolerance, however, it appears that most benefits are obtained at moderate or vigorous intensity. It is recommended for patients with advanced disease that exercise be conducted under supervision or guidance, with careful consideration of any potential risks or contraindications given the complexities that commonly present in this stage of diagnosis.<sup>17</sup> Table 1 was developed to collate the recommendations from this review to assist clinicians with exercise prescription for people diagnosed with lung cancer. Fig. 1 provides a general overview of exercise for people with lung cancer.

## 13. Future research and current gaps

Future research in exercise and lung cancer could contribute significantly to improving the care and quality of life of individuals affected by this debilitating disease. Very little exercise evidence in small cell carcinoma currently exists with the majority of evidence in non-small cell lung carcinoma. Health economic analyses should be conducted alongside future RCTs. More research is needed to determine how exercise programmes can be further tailored to the unique needs and capabilities of each individual patient with lung cancer. This includes addressing the specific challenges faced by different subgroups, such as older adults, those with comorbidities, or patients with different histological types of



Fig. 1. The impact of exercise on people with lung cancer.

lung cancer. Research should focus on the safety of exercise interventions, especially during active cancer treatment phases or in people with bony metastases. This includes understanding the potential interactions between exercise and specific treatments and identifying strategies to mitigate adverse effects. The current body of evidence has involved the prescription of multi-modal exercise. Future research should include head-to-head comparisons of the effects of different training types. Long-term studies are needed to assess the sustained benefits of exercise in lung cancer survivors, including the impact on cancer recurrence, overall survival, and the prevention of cancer-related comorbidities. Understanding the underlying mechanisms and best practices for symptom management through exercise is crucial. Researchers should explore how exercise can complement other treatments and interventions (and



be delivered adjunctly by qualified professionals – such as clinical exercise physiologists and physiotherapists – as part of the care team), such as nutritional support, pharmacological agents, and psychosocial interventions, to enhance overall best practice patient care.

Further research is needed into our understanding of the underlying mechanisms through which exercise exerts positive effects on lung cancer outcomes. This could provide insights into potential targets for therapeutic interventions. Understanding the role of exercise in improving the quality of life and symptom management in individuals with advanced lung cancer and in palliative care is an area of importance. Collaboration between researchers, clinicians, patients, and advocacy groups is crucial to advancing the field of exercise and lung cancer. By addressing these research gaps, we can better define the role of exercise in lung cancer care, target limited resources to responders and develop evidence-based strategies to optimise the physical and emotional well-being of individuals living with this disease.

## 14. Conclusion

Lung cancer is a global health concern with lower survival rates and significant patient burdens. Given increased treatment options and gradually improving survival exercise is gaining interest as an adjunct therapy to improve health outcomes, particularly for patients with lung cancer. However, their specific needs such as capacity for exercise and symptoms need to be at the forefront of care. This review provides new insights into exercise in lung cancer care, emphasising the need for further research to optimise exercise prescriptions. Whilst patients may not be routinely referred to services/programmes due to inconsistent referral pathways, our recommendations encourage the use of moderate–vigorous–intensity cardiorespiratory exercise, resistance training, and individualised programmes which can be tailored to the resources available in each clinical setting. Research to date has demonstrated that exercise has a positive effect in people with lung cancer regardless of stage, from preoperative to postoperative care, as well as in advanced cancer. Successful exercise interventions require tailored programmes, specialised healthcare providers, and a focus on adherence strategies. Adherence can be improved through education, goal setting, and caregiver support. Addressing these areas can enhance the well-being of patients with lung cancer and potentially improve outcomes.

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## CRedit authorship contribution statement

Concept/design: K. Toohey; systematic data search: K. Toohey, P. Lopez, B. Singh and M. Hunter; data screening and extraction: all listed authors; data analysis: K. Toohey; data interpretation: K. Toohey and S. Hayes; draft: K. Toohey; and critical revision, writing contribution and approval: all listed authors.

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