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## TITLE PAGE

Understanding factors influencing physical activity and exercise in lung cancer: a systematic review

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## **ABSTRACT**

**Purpose:** Despite evidence and clinical practice guidelines supporting physical activity (PA) for people with lung cancer, this evidence has not translated into clinical practice. This review aims to identify, evaluate and synthesise studies examining the barriers and enablers for patients with lung cancer to participate in PA from the perspective of patients, carers and health-care providers (HCPs).

**Methods:** Systematic review of articles using electronic databases: MEDLINE (1950-2016), CINAHL (1982-2016), EMBASE (1980-2016), Scopus (2004-2016) and Cochrane (2016). Quantitative and qualitative studies, published in English in a peer-reviewed journal, which assessed the barriers or enablers to PA for patients with lung cancer were included. Registered- PROSPERO (CRD4201603341).

**Results:** 26 studies (n=9 cross-sectional, n=4 case series, n=11 qualitative) including 1074 patients, 23 carers and 169 HCPs were included. Barriers and enablers to PA were identified (6 major themes, 18 sub-themes): Barriers included patient-level factors (physical capability, symptoms, comorbidities, previous sedentary lifestyle, psychological influences, perceived relevance); HCPs factors (time/knowledge to deliver information); and environmental factors (access to services, resources, timing relative to treatment). Enablers included anticipated benefits, opportunity for behaviour change and influences from HCPs and carers.

**Conclusion:** This systematic review has identified the volume of literature demonstrating that barriers and enablers to PA in lung cancer are multi-dimensional and span diverse factors. These include patients level factors, such as symptoms, comorbidities, sedentary lifestyle, mood and fear, and environmental factors. These factors should be considered to identify and develop suitable interventions and clinical services in attempt to increase PA in patients with lung cancer.

**Key words:** lung cancer; physical activity; exercise; barriers; systematic review

## **INTRODUCTION**

Lung cancer is associated with significant multi-system disability and impairment [1]. Exercise intolerance occurs due to several confounding factors including the underlying pathological process, effect of surgical/adjuvant treatment, existing comorbidity, and a history of sedentary behaviour [1-3]. Patients experience high symptom levels, particularly dyspnoea and fatigue [4]. These exacerbate patient distress and interfere with daily activities[4], and result in a vicious spiral of decline in physical function, cardiovascular fitness and muscle strength [5]. Ramifications for the patient (activity limitations, participation restrictions and diminished health-related quality of life [HRQoL]) and health-care system (hospital utilization) ensue [1, 5, 6].

Exercise is an effective means to improve physical and psychological outcomes in lung cancer [7-10]. The body of evidence has developed rapidly, and results from primary studies and systematic reviews/meta-analyses inform the current international clinical guidelines developed by the American College of Sports Medicine and American Cancer Society [2, 11]. These guidelines send a consistent message to consumers (patients, carers, health-care providers [HCPs] and policy makers): patients with cancer should engage in 150 minutes of moderate-intensity physical activity (PA) and 2-3 resistance sessions per week and avoid sedentary time [2, 11]. However despite the large body of evidence, translation into lung cancer clinical practice and policy is almost non-existent. Exercise is not routinely delivered as part of the lung cancer model of care worldwide, as opposed to other populations such as chronic obstructive pulmonary disease (COPD) where pulmonary rehabilitation is standard practice [8]. This is problematic because patients with lung cancer have significant unmet needs, are inactive and rarely meet PA guidelines [5, 12]. The reason for the failure of evidence translation is not clear. Therefore, the aim of this systematic review was to identify, evaluate and synthesise studies examining the barriers and enablers for patients with lung cancer to participate in PA and thereby inform clinical practice, service delivery, policy and research aiming to enhance PA levels.

## **METHODS**

### **Protocol**

The protocol is registered with the International prospective register of systematic reviews PROSPERO (CRD4201603341). The Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines [13] and Enhanced Transparency of Reporting the Synthesis of Qualitative Research (ENTREQ) framework [14] were followed.

### **Eligibility criteria**

Eligibility criteria are described in Table 1. Studies examining the barriers or enablers to patients with lung cancer participating in PA (any bodily movement produced by skeletal muscles that results in energy expenditure) [15] were included.

### **Information sources and search**

Five electronic databases (Figure 1) were searched by one reviewer (SP) using a pre-planned, systematic, comprehensive and reproducible search strategy to identify all published studies against defined eligibility criteria. Search terms and full search strategy are available in the online supplementary Table E1. Databases were accessed via The University of Melbourne. The last search was run on 1<sup>st</sup> February 2016. Additional references were identified by cross-referencing reference lists of included articles and hand-searching personal files.

### **Study selection**

Eligibility assessment was performed in a standardised manner (Figure 1). Two reviewers (CG, SP) independently screened abstracts and subsequently full-text articles for inclusion against defined eligibility criteria (Table 1). Disagreement was resolved by consensus, with a third reviewer (BC) involved if necessary. At each assessment stage the agreement between reviewers was estimated with percentage agreement and the Kappa statistic using SPSS for Windows statistical software package (SPSS<sup>o</sup>Inc., Version22.0.0, Chicago, IL). All references were stored in Endnote software 2016 versionX7.4.

### **Data collection process and data items**

Data extraction for *quantitative* studies was performed using a bespoke data collection form by reviewers (BC, KL) and cross-checked by a second (KL, BC). Independent reviewers (CG, SP) manually extracted and cross-checked all text under ‘results/conclusions’ from *qualitative* studies. To avoid double counting data, multiple reports on the same participant sample were identified by juxtaposing extracted data. Collected data were stored using Microsoft<sup>(R)</sup>Office Excel<sup>(R)</sup> 2016 software.

### **Risk of bias in individual studies**

Independent reviewers (SP, CG) assessed the risk of bias of studies. Scoring agreement was estimated with percentage agreement and the Kappa statistic. Case series were assessed using the Newcastle–Ottawa Quality Assessment Scale (NOS) [16] Cross-sectional studies were assessed using the Agency for Healthcare Research and Quality Methodology Checklist for Cross-Sectional/Prevalence Studies [17]. *Qualitative* studies were assessed using the Consolidated criteria for reporting qualitative research (COREQ) checklist [18]. Higher scores represent lower risk of bias (*quantitative* studies)

[16, 17] or better comprehensiveness of reporting (*qualitative* studies) [18]. Results of studies were given the same weight regardless of their assessed risk of bias.

## **Synthesis of results**

*Quantitative* data were summarised using descriptive statistics and frequencies using SPSS for Windows statistical software package (SPSS<sup>o</sup>Inc., Version22.0.0 Chicago, IL) and data on barriers and enablers to PA were synthesized in a narrative format. A meta-analysis was not possible due to variability in selection of reported outcome measures. *Qualitative* data on barriers and enablers were synthesised using thematic synthesis [19]. Two independent reviewers performed line-by-line coding of text from the qualitative studies (SP and CG), and similar concepts were grouped and new codes developed when necessary. Free codes were organised into descriptive major themes and sub-themes using an inductive approach [19]. *Qualitative* studies were crosschecked to ensure relevant data were captured and integrated into the themes.

Results were mapped to the ‘capability, opportunity, motivation - behaviour (COM-B) system’ [20]. Capability refers to the capacity to engage in the behaviour; motivation refers to brain processes that energise and direct behaviour; and opportunity refers to factors external to the patient that act as a barrier or enabler to the behaviour [20]. The COM-B system links to the published ‘Behaviour Change Wheel’ [20] which provides a systematic framework to map behavioural analyses to specific interventions and policies aiming. Results of this review were interpreted in within the COM-B system (i.e. whether barriers were related to capability, opportunity or motivational issues). Results of this review were interpreted in within the COM-B system (i.e. whether barriers were related to capability, opportunity or motivational issues).

## **RESULTS**

### **Study selection**

The search yielded a total of 2,046 studies (Figure 1). Assessment of title, abstract and full text resulted in 26 papers on 24 unique participant samples being selected for inclusion (Figure 1). Agreement between reviewers of titles/abstracts was ‘substantial’ (Kappa=0.7, percentage agreement = 93%) and full-text articles were ‘almost perfect’ (Kappa=0.9, percentage agreement = 95%). Consensus was achieved on 100% of occasions when reviewers disagreed. Arbitration from a third reviewer was not required.

INSERT FIGURE 1

### **Study characteristics**

This review included four prospective case series [21-24], nine cross-sectional studies [25-35], and 11 *qualitative* studies (Table 2) [36-46]. Studies were conducted in eight different countries; the most common were United States (25% of studies), Canada (21%) and United Kingdom (17%) (Table 2). Most studies (79%) included only patients with lung cancer. Overall 1074 patients with lung cancer, 169 HCPs and 23 carers were included in the review. Half of the studies included patients after treatment, and other studies included patients during (18%) or before (9%) treatment, or at variable times (14%). The majority (73%) of *qualitative* studies used semi-structured interviews to collect data on barriers and enablers (online supplementary Table E2). All *quantitative* studies used questionnaires to collect data on barriers and enablers however there was not one consistent questionnaire used and the majority (62%) used their own self-designed survey (online supplementary Table E2).

### **Risk of bias in studies**

Agreement between reviewers for scoring was ‘almost perfect’ (Kappa=0.9, percentage agreement = 97%). Consensus was achieved on all occasions when reviewers disagreed. Risk of bias was predominately attributed to be due to lack of comparability for case series and inadequate reporting of the recruitment time period or handling of missing data for cross-sectional studies. Qualitative studies scored poorly for lack of reporting of the interviewers’ characteristics and the relationship between interviewers and participants. The mean (SD) risk of bias score for case series was 4.2 (1.0) out of 8 on the Newcastle–Ottawa Quality Assessment Scale (NOS) [16]; for cross-sectional studies was 8.2 (1.4) out of 11 on the Agency for Healthcare Research and Quality Methodology Checklist for Cross-Sectional/Prevalence Studies [17]; and for qualitative studies was 16.4 (2.6) out of 32 on the COREQ checklist [18] showing the overall risk of bias was moderate to high (online supplementary Table E3).

### **Synthesis of results**

Six major themes and 18 sub-themes for barriers and enablers to PA were identified across the 24 studies (Table 3, Figure 2). Patient quotes from primary qualitative studies are provided to reflect themes.

#### *Theme 1: Patient motivation and beliefs*

The anticipated impact of PA was reported by patients [25, 34, 36, 37, 39, 40, 42, 44-46] and this was predominately seen as an enabler and motivator for PA. Anticipated benefits included improvements in physical health, facilitating return to work and being able to fight the disease. Other patient beliefs were that PA would help gain control over the disease, be a distraction, relieve stress, improve HRQoL and provide social benefits especially from exercising in a group.

*“You hope that by exercising, you can improve physically and your quality of life, and also maybe prevent other illnesses” [36]*

The expected impact of PA on symptoms varied with anticipated improvements [25, 42, 45] and harm [37, 44, 46] reported by patients. For the latter, patients expressed fear and avoidance of PA in the belief that it could worsen their symptoms, which may then not resolve.

Patients experienced positive outcomes from PA and this was seen as an enabler to continue PA [23-25, 36, 40, 44, 45]. They reported improvements in physical health, psychological health and symptoms with PA, as well as functional deterioration following cessation of PA.

*“The Wii is – is a fantastic machine. I’m still using it, and I have almost 213 hours on it now. I look forward to using it in the morning because it gets endorphins in the brain going, and it starts me for the rest of the day” [40]*

#### *Theme 2: Patient pre-diagnosis PA habits and perceived relevance*

Previous PA history strongly influenced patients’ current participation in PA [25, 36, 37, 41, 42, 44, 45]. Patients who had exercised previously were more motivated to exercise after diagnosis. Patients described themselves, as being “exercisers” or “non-exercisers” and the ‘non-exercisers’ preferred to do usual activities for PA, such as walking, as opposed to structured exercise. The experience of physical discomfort following PA (as a result of being unaccustomed to PA) was reported as a barrier and hindered adherence. Some patients recognised cancer as an opportunity for behaviour change and a trigger to start exercising; others expressed lack of interest and were not willing to try something new. Perceived relevance was identified [37, 43] as an important factor for enabling PA [37, 43] and unless benefits were thought to be achieved in the short-term, patients felt that they were unlikely to participate in PA especially given their poor prognosis.

*“I’ve never exercised before and I have never wanted to” [45]*

#### *Theme 3: Physical influences*

Symptoms were reported as barriers to PA [23, 25, 35-37, 39, 40, 44, 45] and resulted in less PA, poor adherence and withdrawal from programs. Fatigue was the most commonly cited symptom and symptoms during chemotherapy were a common barrier (Table 3). Medical complications including post-operative complications delaying mobilisation and hospital readmissions were barriers to PA [23, 34, 36, 37, 39-42, 45]. In six studies [25, 34, 37, 42-44] comorbidities were noted as a barrier to PA. Older age, lower education and smoking history were seen in patients who were less active or less motivated to be active/change behaviour [31, 34].

*“I have had my knees replaced. I have got arthritis, also. It is hard to blame this [on] lung cancer or chemo or being 66 years old. I mean it is some of all three, I’m sure” [44]*

#### *Theme 4: Psychological influences*

Psychological factors were identified by patients as barriers to PA [25, 29, 31, 37, 40, 42, 46]. These included fear of exercise, lack of confidence, depression, anxiety, feeling overwhelmed, difficulty adapting to diagnosis, and introversion. These factors were especially noted to be barriers at time of diagnosis and during treatment.

*“I don’t trust my body. Maybe at the last minute I will be paralysed by anxiety or I will be bothered by persistent constipation or a bronchial infection” [37]*

#### *Theme 5: Social influences*

Carers and relatives were noted as a source of motivation and encouragement for PA [23, 25, 34, 37, 43]. Patients relied on caregivers to recall information. However, in two studies [37, 43] carers and relatives were seen as a barrier. Some patients reported that carers/relatives believed that they were not able to be active and that PA would be harmful. Patients identified that encouragement of PA by HCPs was a key enabler and lack of it was a large barrier [24, 25, 37, 44].

*“When you have a prognosis of six months, it is hard to motivate yourself to get in shape, knowing that at some point the disease will come...When you are sick, you lose a lot of psychic autonomy and your ability for decision making...However, if there is a professional PA teacher to push you, there is no need for questioning or thinking about this issue.” [37]*

#### *Theme 6: Environmental and structural influences*

In 15 studies [21, 23-28, 30, 36-38, 42-45] patients reported preferences for PA, especially relevant for delivery of exercise programs, which included the venue of exercise, supervision, structure, schedule and exercise type. These factors were noted to either promote or hinder adherence to PA and are described in detail in Table 3. There were conflicting results regarding whether exercising at home was preferred. Preference for home-based exercise ranged from 20%-100% of surveyed patients across the five studies [24, 25, 27, 28, 30]. Two studies [42, 43] highlighted that home-based exercise was an enabler in that it was more convenient, less burdensome (no travel/parking required) and more personal. However, a third study [45] identified home-based exercise as a barrier in that it required the patient to be self-motivated to perform the exercises. Social engagement and supervision were highly sought after by patients, and a benefit of hospital-based exercise. Patients felt supervision provided a sense of security, leadership and means to be monitored/progressed. Transportation was a barrier [23, 25, 39, 42] particularly when patients were medically unable to drive.

*“They wouldn’t let me drive. I didn’t have any way to get to town” [42]*

Exercising in a group compared to alone was explored in seven studies [25, 27, 28, 30, 36, 43, 45] with conflicting results. However generally patients viewed group classes as a positive in that it promoted social engagement and allowed them to be supervised (preference ranged from 19%-27% of surveyed patients).

*“Training in a group is much better because you know that someone is keeping an eye out whether you come or not. It’s a little more difficult when you have to do it on your own.” “We inspire each other to come and it’s nice to be expected and a part of the group” [45]*

The type and format of PA preference was investigated in 10 studies [24, 25, 27, 28, 30, 37, 42-45]. Consistently walking was the preferred type of PA (42%-89% of surveyed patients) and patients also wanted a variety of exercises to prevent boredom (56%-61%). Moderate-intensity exercise was the most preferred intensity (44%-62%). Overall patients reported that they wanted an individualised program, with achievable/meaningful goals, and centred on symptom management and functional independence. The ability to adapt the program based on current symptoms and comorbidities was also important. Convenience of exercise (being able to fit into daily routine) was an enabler, and lack of it was a barrier. Time required to exercise was a barrier to PA [36, 42, 45]. Weather was also a barrier [25, 37, 44] and patients had low resilience to adapt in bad weather.

*“I was real afraid of the effect that winter was going to have on the lungs. The cold air did affect the breathing a lot when I went out. So, yes, I was quite afraid, especially of exercise. Because you just didn’t know.” [44]*

There were diverse results with regards to patient preferences for when to commence a PA program and when to receive PA advice [25-28, 30, 42, 43]. Overall the preferences were highest before treatment for both participation in a program (26%-68%) and for receiving advice (14%-68%). However, in two studies [42, 43] patients highlighted that they would not like receiving advice or to perform PA before or during treatment because they felt overwhelmed and incapable of taking on new information. Patients who received surgery preferred to start PA during adjuvant treatment, whereas patients who did not have surgery preferred to start after completion of treatment. Patients strongly relied on verbal information [27, 28, 30] predominately from their physician on PA [26, 28, 30, 39, 44]. Whilst patients were receptive to receiving PA information (23%-85%) [27, 28, 30] few had received any advice. Patients were confused about how hard to exercise. Contradictory advice from different HCPs (across or within professions) was a frustration [36, 43]. Data from HCP (as opposed to patients) [32, 33] demonstrated a lack of understanding of the potential benefits of PA from the

multi-disciplinary team, lack of knowledge of services, and lack of services as barriers to PA. Telerehabilitation was identified by HCPs as a potential strategy for provision of information [38].

INSERT FIGURE 2

## **DISCUSSION**

This review has identified the barriers and enablers to patients with lung cancer participating in PA, the evidence of which predominately comes from studies including patients themselves rather than from HCPs or carers. Lack of PA is a significant issue in lung cancer [5, 12] and limited evidence translation into clinical practice necessitates the development of new strategies and models of care aiming to enhance PA. Importantly this review has identified a number of potentially modifiable patient-reported barriers, and a variety of enablers, which should be targeted and utilised to inform future clinical practice. Implementing evidence into practice is a highly challenging task and one strategy that has been developed to facilitate this is the COM-B model [20] and associated Behavioural Change Wheel [20]. Our results can be interpreted within the COM-B model. For example, capability-related barriers to PA included symptoms and comorbidities, opportunity-related barriers included lack of access to services, and motivation-related barriers included fear of PA and perceived relevance. In contrast enablers for PA mapped to these domains included personal preferences for PA, encouragement from carers and HCPs (opportunity), and anticipated benefits from PA (motivation). To change practice or behaviour, one or multiple aspects of the COM-B model can be targeted with interventions (in research or clinical practice). Based on this framework and our results, we recommend potential interventions to target in lung cancer are education (of patients, carers and HCPs), persuasion (of HCPs and patients), training (HCPs), environmental restructuring, modelling and enablement [20]. These strategies could be used to inform the development of new interventions attempting to reduce barriers and take advantage of enablers, and thus increase PA in lung cancer. Such an intervention could target a number of these factors at once. For example, a multidimensional interventional program which could be tested in the future may be one that educates HCPs working in the area of lung cancer about PA through an online training program, that in turn facilitates HCPs to educate their patients/carers about PA; combined with a system of integrated online prompts during patient consults for the HCP to ask their patients about their current PA levels.

Results show clear messages from patients about their desire for individualised care. This is evident across a number of aspects spanning from the delivery of exercise programs, type of PA and timing relative to treatment. Whilst there were a small number of trends found in patient preferences, for example patients predominately preferred walking as their main type of PA, overall there was inconsistency within and across primary studies. We hypothesize this is due to the diversity of patient personal preferences, which is also evident within the general population. Therefore, in attempt to

enable patients with lung cancer to become and stay active, flexibility needs to be added into the delivery of healthcare services. An appealing model is one where patients could select from a variety of options, including when, where and how they will exercise. Individualised care is also highly important given the elderly age and high incidence of multimorbidities especially COPD in this population. In COPD, pulmonary rehabilitation was traditionally implemented in a standardised format, with little variability across institutions or countries. There is now a recent shift towards more individualised care in COPD, especially given the highly complexity of patients and impact of multimorbidities. Telerehabilitation is being actively investigated in COPD pulmonary rehabilitation [47] and may be a potential strategy to facilitate patients with lung cancer to exercise as well, particularly for those who have barriers to access services. In the COPD population there are a number of different pulmonary rehabilitation models in use or being researched at present in attempt to improve physical activity levels. These include the use of smart phone applications to stimulate physical activity [48], communication with therapist via the internet for motivation [48], and supervised home exercise training with real time remote videoconferencing [49]. These models could be applied to the lung cancer population as well. Flexibility is easier to implement in clinical practice, but challenging to use in a RCT design, however studies investigating the efficacy of this model in lung cancer would be highly beneficial. Potentially a stepped care model may be appropriate in lung cancer, where patients could be offered an escalating number of treatment options depending on their own need at that point in time.

This review found that patients preferred to receive information about PA initially from their treating doctor and prior to treatment commencing, reflecting the perceived high importance patients place on their primary doctor for their overall cancer management and is not a new finding for the cancer literature. Capitalising on the opportunity of lung cancer doctors to discuss and recommend PA during patient consultations represents a powerful strategy to directly influence behaviour. Patients deemed to be inactive could subsequently be referred to a physiotherapist, kinesiologist or accredited exercise specialist for a detailed assessment and treatment plan. In order to optimise success of this approach, efforts to enhance the education and training of the multi-disciplinary team regarding PA, to address the barrier of perceived lack of knowledge on the part of HCPs, would be required. Symptom modification from PA was also evident as both a barrier and enabler. We found that many patients expected positive outcomes from PA including reduction in symptoms, yet others feared and avoided PA due to the belief that PA may worsen symptoms. In addition, carers often blocked PA with the thought it may be harmful. Evidence from systematic reviews shows that exercise is associated with strong and consistent improvements in fitness, muscle strength, HRQoL and symptoms in cancer [2, 11] and therefore this is an important message to be relayed to patients and carers by all HCPs as patients move along the care pathway. Reinforcement of this message by the entire multi-disciplinary team is important.

Our results are not dissimilar to findings from other cancer populations [50, 51]. In breast cancer, factors influencing physical activity are psychological (motivation, fear, dislike), physical (ageing, cancer treatment, co-morbidities, fatigue, weight gain) and contextual and environment barriers [50]. Similarly, in prostate cancer factors include clinician and spouse influences, comorbidities, fatigue and lack of advice [51]. This suggests that a larger approach may be needed to effectively implement exercise into the model of cancer care, more broadly than for just the lung cancer population.

This review is strengthened by inclusion of qualitative and quantitative data [14]. In particular the 'patient voice' has featured prominently in this review. However, there is a clear gap in the data from the limited number of studies including HCPs. These studies found important barriers and further research is required to explore these issues. We followed a robust protocol, review guidelines [13, 14], and incorporated duplicate screening, data extraction and risk of bias assessment to enhance review rigour. Only one study was excluded through non-publication in English. All studies were included regardless of risk of bias and therefore results from primary studies should be taken with caution. The study is also limited by the lack of randomised trials and overall low level of evidence of included primary studies, however these are clear gaps in the literature which should be addressed with future research.

This systematic review has identified the volume of literature reporting on barriers and enablers to physical activity in lung cancer. Barriers and enablers are multi-dimensional and span diverse factors. Patient barriers include physical capability (symptoms, comorbidities), psychological influences, previous sedentary lifestyle and perceived relevance. Enablers include anticipated benefits of PA, opportunity for behaviour change and social influences from HCPs and carers. Patients strongly desire individualised PA programs. Considering these factors in a structured behavioural change framework has elucidated potential mechanisms for enhancing interventions and clinical services to increase PA in patients with lung cancer.

**Conflict of interest:** The work of two authors (CG, LD) was included as a primary study in this review [29].

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**Abbreviations:**

Consolidated criteria for reporting qualitative research, COREQ

Capability, Opportunity Motivation – Behaviour, COM-B system  
Chronic Obstructive Pulmonary Disease, COPD  
Enhanced Transparency of Reporting the Synthesis of Qualitative Research, ENTREQ  
Health-Care Providers, HCPs  
Health-Related Quality of Life, HRQoL  
International prospective register of systematic reviews, PROSPERO  
Newcastle–Ottawa Quality Assessment Scale, NOS  
Physical Activity, PA  
Preferred Reporting Items for Systematic Reviews and Meta-analyses, PRISMA

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**Figure captions:**

**Figure 1: PRISMA Flow diagram of study selection process**

*Abbreviations: <, less than; CINAHL, Cumulative Index to Nursing and Allied Health Literature; EMBASE, the Excerpta Medica Database; PA, physical activity.*

**Figure 2: Results: Factors (barriers and enablers) influencing physical activity in lung cancer mapped using the COM-B Model [20]**

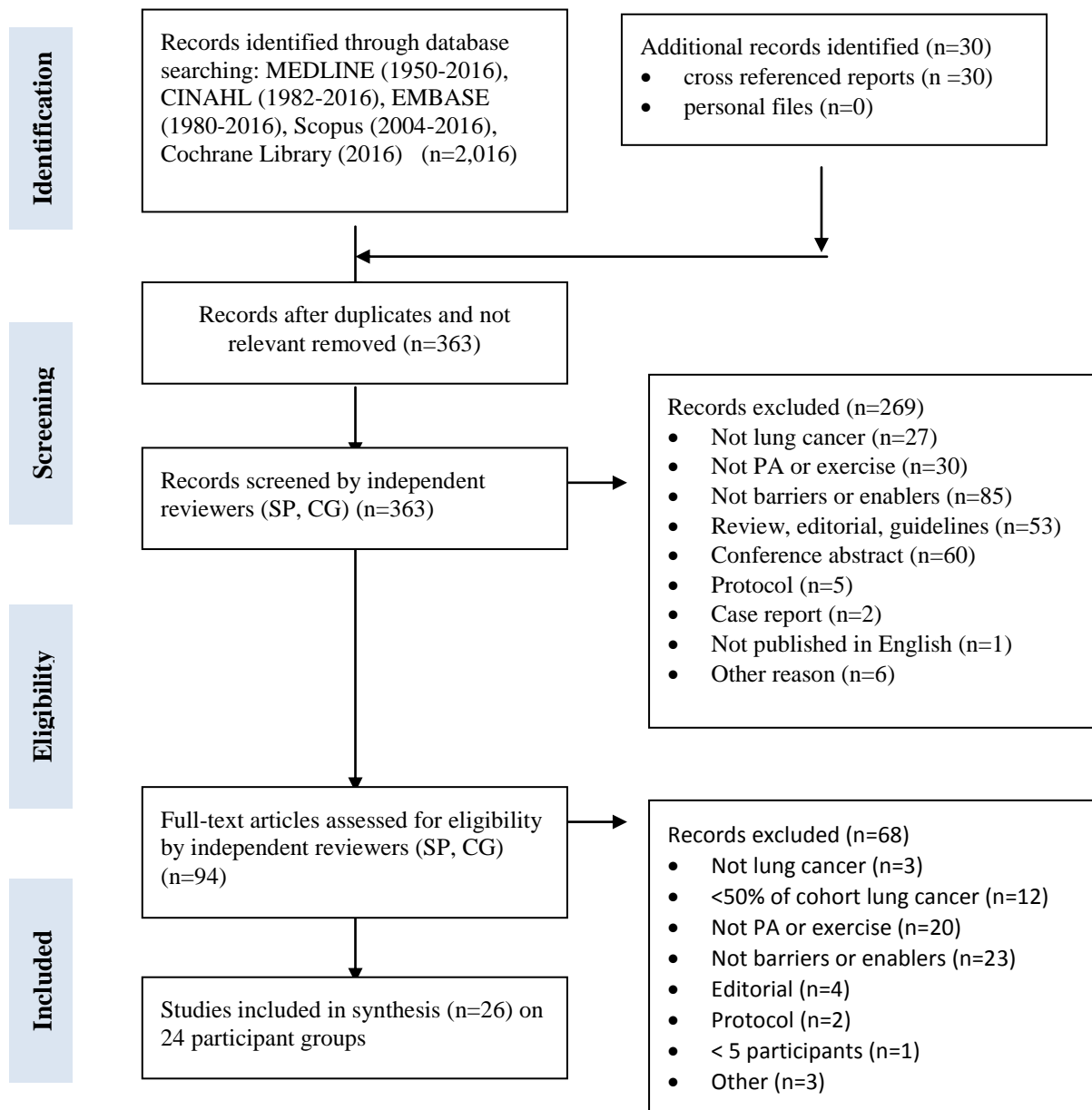
*Abbreviations: COM-B, 'Capability, Opportunity and Motivation-Behaviour' system; HCP, health-care provider; PA, physical activity.*

**List of supplementary material:**

**Online supplementary table E1: Search strategy**

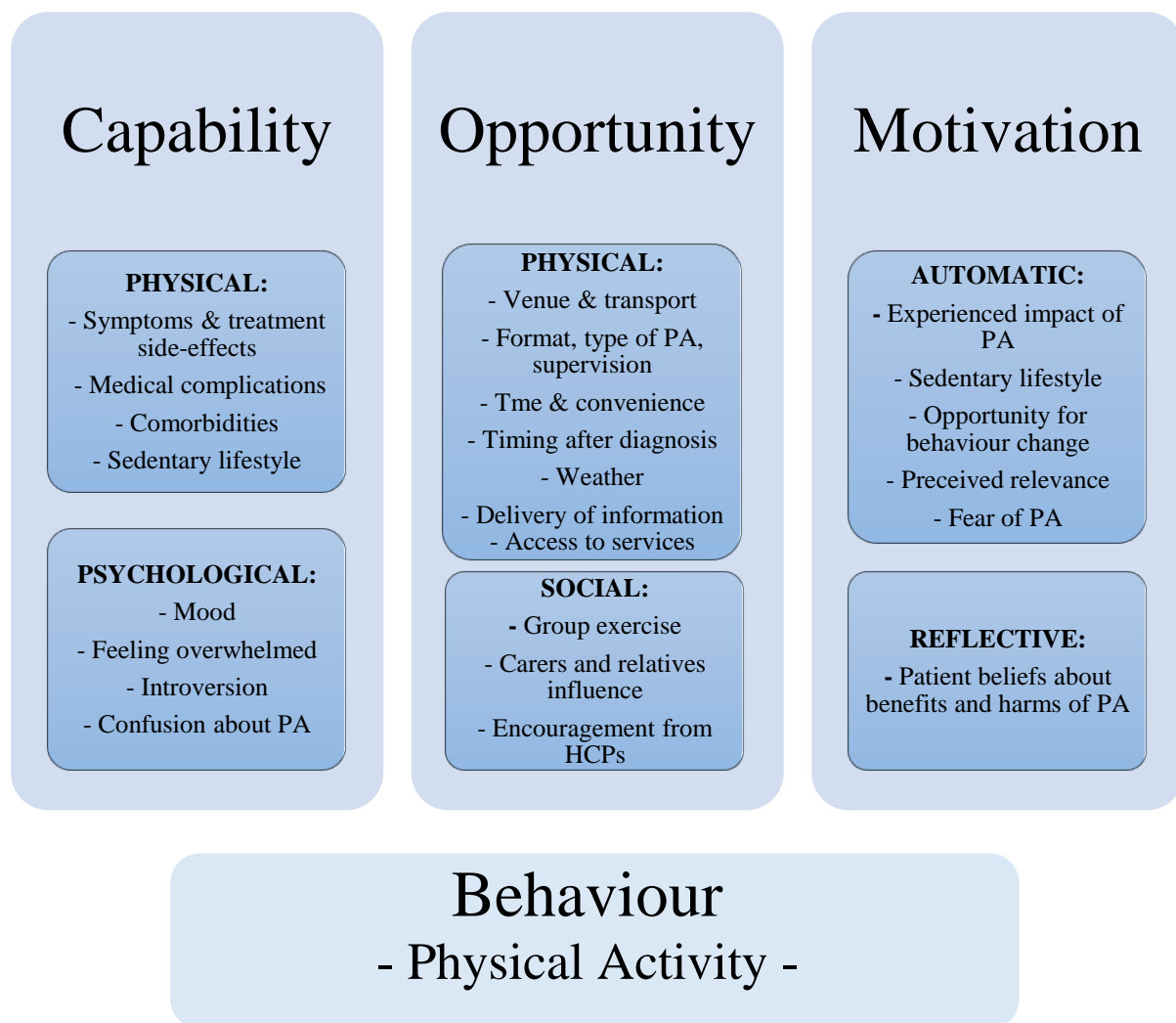
**Online supplementary table E2: Study aims and methodology**

**Online supplementary table E3: Risk of bias in primary studies**



**Figure 1: PRISMA Flow diagram of study selection process**

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**Figure 2: Results: Factors (barriers and enablers) influencing physical activity in lung cancer mapped using the COM-B Model [16]**

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**Table 1: Eligibility criteria for inclusion of primary studies in the systematic review**

<b>Characteristics</b>	<b>Inclusion</b>	<b>Exclusion</b>
Study design	<ul style="list-style-type: none"><li>• Quantitative including RCTs, pseudo-RCTs, cohort studies, case-control studies, case series, cross-sectional studies; or</li><li>• Qualitative</li></ul>	<ul style="list-style-type: none"><li>• No original participant data (editorials, review papers, clinical guidelines)</li><li>• Conference abstracts</li></ul>
Participants	<ul style="list-style-type: none"><li>• People with a current or previous diagnosis of lung cancer; or</li><li>• Carers or relatives of people with lung cancer; or</li><li>• HCPs working with patients with lung cancer</li></ul>	<ul style="list-style-type: none"><li>• Studies with less than five participants</li><li>• Studies with mixed cancer cohorts if &lt; 50% of the cohort had lung cancer and/or cohort with lung cancer was not analysed separately</li></ul>
Exposure	<ul style="list-style-type: none"><li>• Participation in PA defined as “any bodily movement produced by skeletal muscles that results in energy expenditure” [15] by people with lung cancer. Includes PA domains of household, occupation, transport, activities of daily living, leisure, sport and structured exercise training.</li></ul>	
Outcomes	<ul style="list-style-type: none"><li>• Barriers and enablers to PA for people with lung cancer</li></ul>	
Publication	<ul style="list-style-type: none"><li>• Published in English</li><li>• Any date of publication</li></ul>	<ul style="list-style-type: none"><li>• Not published in a peer reviewed journal</li></ul>

*Abbreviations: HCPs, health care providers; PA, physical activity; RCT, randomized controlled trial.*

**Table 2: Characteristics of primary studies**

Author, yr, country	Type of participants (number)	Gender M:F	Age years mean $\pm$ SD	Cancer type and stage (n)%	Time relative to cancer treatment (n)%	Cancer treatment (n)%
Qualitative studies						
Brown 2015, Australia [39]	Lung cancer (10)	8:2	Range 50-89	Lung (10) 100% Stage N/R	During treatment (2) 20%; post-treatment (5) 50%; pall care (3) 30%	N/R
Kuijpers 2015, The Netherlands [38]	Lung cancer (14); breast cancer (21); HCPs (31): medical (n=7 e.g. radiotherapists, nurse practitioners), paramedical (n=10 e.g. physical therapists, dieticians), and psychosocial (n=14 e.g. social workers, psychiatrist)	Lung cancer 7:7 Breast cancer 0:21 HCPs 6:25	Lung cancer: 61.6 (range 52-79) Breast cancer: 52.9 (range 27-76) HCPs: 45.5 (range 24-62)	Lung (14) 40% Breast (21) 60%	Lung cancer: <1yr after treatment, 14 (100)  Breast cancer: <1yr after treatment, 9 (43%); >1-5yr after treatment, 12 (57%)	N/R
Mas 2015, France [37]	Lung cancer (5)	4:1	69 (range 60-81)	NSCLC IIIB (5) 100%	During chemo	Surgery+chemo (4) 80%; chemo only (1) 20%
Missel 2015, Denmark [36]	Lung cancer (19)	8:11	63 (range 48-75)	NSCLC: IA (5) 26%; IB (1) 5%; IIA (9) 47%; IIB (2) 10%; III (2) 10%	Post-operative (day 1, 7 weeks and 4 months post)	Surgery only (11) 68%; surgery+chemo (8) 42%
Hoffman 2014, US [40]	Lung cancer (6)	2:4	Range 53-73	NSCLC: I (1) 17%; II (3) 50%; III (2) 33%	12-18 months post-op	Surgery, chemo+RT (3) 50%; surgery+chemo (2) 33%; surgery only (1) 17%
Lehto 2013, US [42]	Lung cancer (11)	5:6	69.8 $\pm$ 8.5	NSCLC: I-II (6) 55%; III-IV (5) 45%	> 6 months post diagnosis	Surgery (7) 64%; chemo (3) 27%; RT+/or chemo (1) 9%
Maddocks 2013, UK [41]	Lung cancer (30)	16:14	70 (IQR 64-74)	NSCLC IV (30) 100%	During chemo	Palliative chemo

Adamsen 2012, Denmark [45]	Lung cancer (15)	8:7	66 (range 45-80)	NSCLC (13) 87%: IIB (7) 54%; IV (2) 15%; unknown (4) 31% SCLC ED (2) 13%	During chemo	Chemo only (5) 33%; chemo+RT (10) 67%
Cheville 2012, US [44]	Lung cancer (20)	10:10	Range 53-84	NSCLC: IIB (2) 10%; IV (18) 90%	NR	Chemo (11) 55%; RT (1) 5%; nil (8) 40%
Ellis 2012, UK [43]	Lung cancer (37); caregivers (23)	Lung cancer- 22:15 Caregivers- NR	Lung cancer- 69.5±8.9 (range 48-91) Caregivers- NR	NSCLC (16) 43.2%; SCLC (19) 51.4%; mesothelioma (2) 5.4% I (1) 3.1%; II (7) 21.8%; III (10) 30.3%; IV (12) 44.8%; 5 missing data	During or post treatment	Chemo+RT (17) 45.9%; chemo only (12) 32.4%; RT only (6) 16.2%; surgery only (1) 2.7%; surgery+chemo (1) 2.7%
Jones 2009, UK [46]	Lung cancer (6)	2:4	Range 43-68	Lung 6 (100%)	Post-operative (6wks-16mnths)	Surgery
Quantitative studies						
Kartolo 2016, Canada [25]	Lung cancer (60)	29:31	Range 41-50 (n=1) Range 51-60 (n=11) Range 61-70 (n=18) Range >70 (n=30)	Inoperable metastatic lung (60) 100%	Within 5 years of diagnosis	Current treatment: chemo (24) 42.1%; oral medication (7) 12.3%; RT (9) 15.8%; nil (17) 29.8%
Leach 2015, Canada [27]	Lung cancer (66)	31:35	66.4±9.1 (range 42-84)	NSCLC (57) 86%: I (8) 13.7%; II (6) 10.6%; III (18) 31.8%; IV (16) 30.3%; not known n=9 SCLC (9) 13%	31.7±22.9months (range 4m-11.5years)	Surgery (13) 19.70%; chemo (53) 78.8%; RT (54) 81.8%
Philip 2014, 2015, US [26, 28]	Lung cancer (175)	61:111	68.7±9.6	IA (122) 69.7%; N/R (53) 30.3%	Mean (SD) 3.6±1.2yrs post treatment	Surgery only (160) 91.4%; N/R (15) 8.6%

Granger 2014, Australia [29]	Lung cancer (50)	32:18	68.5±9.3	NSCLC: I (21) 43%; II (10) 20%; III (18) 37%	Pre-treatment	RT (11) 22%; chemo+RT (10) 20%; surgery+chemo (12) 24%; surgery only (12) 28%; surgery, chemo+RT (1) 2%; nil (1) 2%
Andersen 2013, Denmark [22]	Lung cancer (51)	31:20	M 65±8 F 65±7	NSCLC (39) 76%; SCLC (10) 20%; N/R (2) 4% Stage NR	NR	Surgery (10) 20%; during chemo (26) 51%; during RT (3) 6%; during TKI (2) 4%
Cavelheri 2013, Australia [32]	Physiotherapists (43)	N/R	N/R	N/A	N/A	N/A
Hoffman 2013, USA [24]	Lung cancer (7)	2:5	64.6±6.5 (range 53- 73)	NSCLC: IA (1) 14.3%; IB (1) 14.3%; IIA (1) 14.3%; IIB 2 28.6%; III (2) 28.6%	Post-op 100% (some during chemo)	Surgery only (2) 29%; surgery+chemo (4) 57%; surgery, chemo+RT (1) 14%
Lebel 2013, Canada* [31]	Lung cancer (107) Head and neck cancer (99)	43:64	64±10.5	Lung cancer: local (91) 85.3%; advanced (16) 14.7%	Post-treatment: mean (SD) 1.2±0.9years post diagnosis	Surgery only (73) 68.2%; surgery+chemo (28) 26.2%; surgery+RT (14) 13.1%; surgery+other (6) 5.6%
Lin 2013, Taiwan [30]	Lung cancer (81)	43:38	61.4±11.4 (range 30- 82)	Lung cancer: I (35) 43.2%; II (1) 1.2%; III (17) 21%; IV (20) 24.7%	Post-treatment: mean (SD) 26.1±28.2 months post diagnosis	Surgery (56) 69.1%; RT (15) 18.5%; chemo (43) 53.1%; target therapy (26) 32.1%
Peddle- McIntyre 2013, Canada [21]	Lung cancer (15)	6:9	67±9.9	NSCLC (14) 93%; SCLC (1) 7% I/II/LS (11) 73%; III (4) 27%	Post-treatment: mean (SD) 3.7±2.1years post-treatment	Surgery (13) 87%; adjuvant chemo (5) 33%; chemo+RT (1) 7%; chemo only (1) 7%; RT only (2) 14%

Nwosu 2012, UK [33]	HCPs (59): nurses (22), doctors (20), discharge planner (4), physiotherapist (4), social worker (3), occupational therapist (2), pastoral care (2), MDT coordinator (1), other (1)	N/R	N/R	N/A	N/A	N/A
Coups 2009, US [34]	Lung cancer (175)	61:111	68.4±9.6	NSCLC IIA 122 69.7%; IB 53 30.3%	Post-op: mean (SD) 3.6±1.2years (range 1-6 years)	Surgery only (160) 91.4%; surgery+chemo (14) 8%; surgery+RT (1) 0.6%
Peddle 2009, Canada [23]	Lung cancer (19)	6:13	64±10	NSCLC (13) 67% N/R (6) 33%	Pre-op	Surgery (after study)
Clark 2008, US [35]	Lung cancer (272)	147:125	71±9.9 (range 27-95)	NSCLC (261) 96%; SCLC (11) 4%	Post-treatment (mean 5 years post-diagnosis)	Chemo (68) 25%; surgery (106) 39%; RT (65) 24%

Abbreviations: chemo, chemotherapy; M, male; F, female; HCPs, health care providers; LS, late stage; N/A, not applicable; N/R, not reported; NSCLC, non-small cell lung cancer; pall, palliative; SCLC, small cell lung cancer; RT, radiotherapy; MDT, multidisciplinary team; TKI, tyrosine kinase inhibitor; yr, year.

\* demographics reported are for the lung cancer sub-group only

**Table 3: Summary of results from studies on barriers (-) and enablers (+) to PA**

<b>Themes</b>	<b>Sub-themes, description and references of primary qualitative studies</b>	<b>Results and references of primary quantitative studies</b>
<b>1. Patient motivation and beliefs</b>		
<b>Anticipated impact of PA</b>	<p><i>Physical health:</i></p> <ul style="list-style-type: none"> <li>- Physical benefits including preventing other illnesses, fighting the disease, returning to work and prolonging life [36, 44, 45] (+)</li> </ul> <p><i>Mental health</i></p> <ul style="list-style-type: none"> <li>- Psychological benefits from participating in a study that could potentially help others [42] (+)</li> <li>- Exercise as a distraction and relief of disease related stress[37] (+)</li> </ul> <p><i>Symptoms</i></p> <ul style="list-style-type: none"> <li>- Improve symptoms [42, 45] (+)</li> <li>- Past/current experiences of physical weakness, fatigue, pain and breathing difficulties motivates patients to be active [45] (+)</li> <li>- Fear of exercise being harmful, triggering symptoms or persistence of symptoms after exercise [37, 44, 46] (-)</li> </ul> <p><i>Self-control:</i> Control over disease with exercise [40, 45] (+)</p> <p><i>Maintaining independence</i></p> <ul style="list-style-type: none"> <li>- Social usefulness, feeling of being useful to others and society [37] (+)</li> <li>- Pride by managing independently [39] (+)</li> <li>- Increase knowledge about PA [36] (+)</li> <li>- Strategies to maintain independence (ration energy, take rest breaks or complete tasks more slowly) rather than ask others for assistance [39] (-)</li> </ul> <p><i>Social engagement</i></p> <ul style="list-style-type: none"> <li>- Sense of community, belonging , not feeling alone [36] (+)</li> <li>- Peer support from patients with similar circumstances in group [46] (+)</li> </ul>	<p><i>Physical health</i></p> <ul style="list-style-type: none"> <li>- Improve strength, cardiovascular fitness, flexibility and daily function [25] (+)</li> <li>- PA outcome expectations significantly associated with engagement in moderate or strenuous PA [34] (+)</li> <li>- PA is important and helpful [25] (+)</li> <li>- Important for patient to set own goals [25] (+)</li> </ul> <p><i>Mental health</i></p> <ul style="list-style-type: none"> <li>- Improve HRQoL and sense of wellbeing [25] (+)</li> </ul> <p><i>Symptoms</i></p> <ul style="list-style-type: none"> <li>- Reduce fatigue and improve energy levels [25] (+)</li> </ul>
<b>Experienced impact of PA</b>	<p><i>Physical health</i></p> <ul style="list-style-type: none"> <li>- Improvement in physical and mental health [36, 44, 45] (+)</li> <li>- Deterioration in function (physical/lung) after stopping exercise [36] (+)</li> </ul> <p><i>Mental health</i></p> <ul style="list-style-type: none"> <li>- Exercise is a challenge [36, 45] (+)</li> </ul>	<p><i>Physical health</i></p> <ul style="list-style-type: none"> <li>- Improvement in fitness, lung function, strength, weight loss and recovery from surgery [23] (+)</li> <li>- Physically stressful/challenge [25] (+ &amp; -)</li> <li>- Not enjoyable [25] (-)</li> <li>- “Sore muscles” from participating in</li> </ul>

	<ul style="list-style-type: none"> <li>- Improvement in mental wellbeing, exercise as ‘a break’ [40, 45] (+)</li> <li>- Sense of satisfaction [44] (+)</li> </ul> <p><i>Symptoms</i></p> <ul style="list-style-type: none"> <li>- Positive impact including increased energy levels [36, 40, 44, 45] (+)</li> </ul>	<ul style="list-style-type: none"> <li>- exercise program [23] (-)</li> </ul> <p><i>Mental health</i></p> <ul style="list-style-type: none"> <li>- Improvement in mental state and mood (37% of patients) [23] (+)</li> </ul> <p><i>Symptoms</i></p> <ul style="list-style-type: none"> <li>- Improvement in confidence in ability to manage fatigue [24] (+)</li> </ul>
<b>2. Patient pre-diagnosis PA habits and perceived relevance</b>		
<b>Sedentary lifestyle</b>	<ul style="list-style-type: none"> <li>- Past preferences/patterns inform choice and focus of PA [37, 44] (+ &amp; -)</li> <li>- Physical discomfort associated with unaccustomed exercise [41, 45] (-)</li> </ul>	<ul style="list-style-type: none"> <li>- Past PA history= higher motivation to exercise [25] (+ &amp; -)</li> </ul>
<b>Opportunity for behaviour change</b>	<ul style="list-style-type: none"> <li>- Trigger to restart exercise after being sedentary [36] (+)</li> <li>- Opportunity for behaviour change at time of loss of control [36] (+)</li> <li>- Lack of interest or willingness to try something new [42] (-)</li> </ul>	
<b>Patient perceived relevance</b>	<ul style="list-style-type: none"> <li>- Belief intervention is not relevant at the specific time point [43] (+ &amp; -)</li> <li>- Expected timing of benefits – short [43] (+) or mid to long term [37] (-)</li> <li>- Poor prognosis and limited survival time [37] (-)</li> </ul>	
<b>3. Physical influences</b>		
<b>Symptoms, side-effects, medical complications</b>	<ul style="list-style-type: none"> <li>- Symptoms strongly influence PA levels especially fatigue, nausea, malaise and cold intolerance [36, 37, 39, 40, 44, 45] (-)</li> <li>- Medical complications including infection and fever [36, 37, 39, 40, 45] (-)</li> <li>- Hospitalization [41] (-)</li> <li>- Forgetfulness and cognitive changes [42] (-)</li> <li>- Post-operative SOB and pain in the first month after surgery[40] (-)</li> <li>- Post-operative complications result in delay to mobilization immediately after surgery [36] (-)</li> </ul>	<ul style="list-style-type: none"> <li>- Lower PA: patients treated with combination surgery plus chemo or surgery plus RT [34], and in patients with greater number of surgical complications [34] (-)</li> <li>- Poor adherence: medical illness [23], feeling unwell [25] (-)</li> <li>- Withdrawal from PA: Decline in performance status, increasing fatigue [22] (-)</li> </ul>
<b>Comorbidities</b>	<ul style="list-style-type: none"> <li>- Comorbidities [43, 44] (-)</li> <li>- Functional limitations and patient perception of their ability to exercise [37, 42, 43] (-)</li> </ul>	<ul style="list-style-type: none"> <li>- Lower PA: older age, lower education, lower lung function, smokers, comorbidities [34] (-)</li> <li>- Better adherence: females [22], males [23] (+ &amp; -)</li> <li>- Better uptake: females [28] (+)</li> <li>- Behaviour change: younger patients, RT, non-smoker [31] (+)</li> <li>- Higher motivation: non-COPD, no difference for age, gender, education, income, treatment status, smoking history, ESAS,</li> </ul>

		performance status and other comorbidities [25] (+ & -)
<b>4. Psychological influences</b>		
<b>Psychological factors</b>	<ul style="list-style-type: none"> <li>- Feeling overwhelmed with appointments and information [42] (-)</li> <li>- Becoming introverted after diagnosis [37] (-)</li> <li>- Difficulty adapting to diagnosis [46] (-)</li> <li>- Confusion: not sure how hard to push or how to handle [40] (-)</li> <li>- Fear of exercise [46] (-)</li> </ul>	<ul style="list-style-type: none"> <li>- Lower PA: higher depression, less intrinsic regulation (i.e. gaining pleasure from exercise) [29] (-)</li> <li>- Behaviour change: associated with behavioural self-blame [31] (+)</li> <li>- Higher motivation: associated with belief PA is important, helpful and easy [25], less symptoms [35] (+)</li> <li>- Self-efficacy for PA: associated with mod/strenuous PA[34] (+ &amp; -)</li> <li>- Poor confidence in physical (54%) and emotional (53%) ability[25] (-)</li> </ul>
<b>5. Social influences</b>		
<b>Carers and relatives</b>	<ul style="list-style-type: none"> <li>- Carers, friends and family as source of motivation and encouragement [37, 43] (+)</li> <li>- Without carer motivation PA is difficult [43] (-)</li> <li>- Heavy reliance on caregivers to recall information [43] (+)</li> <li>- Family and friends can promote inactivity to protect patient [37] (-)</li> </ul>	<ul style="list-style-type: none"> <li>- Social support from family: associated with walking [34], facilitated attendance [23], motivation [25] (+)</li> </ul>
<b>HCPs</b>	<ul style="list-style-type: none"> <li>- Physician encouragement or prescription of exercise [37, 44] (+)</li> <li>- Need advice from a specialist to guide PA practice (+) and lack of it is a barrier undertaking PA [37] (-)</li> <li>- Patient desire for a rehabilitation class including information about diet, exercise and lifestyle changes to allow information delivery and questions (similar to cardiac rehabilitation) [46] (+)</li> </ul>	<ul style="list-style-type: none"> <li>- Encouragement from HCP [25] (+)</li> <li>- Interaction with a nurse during telephone calls [24] (+)</li> </ul>
<b>6. Environment and structural influences</b>		
<b>Venue for exercise</b>	<ul style="list-style-type: none"> <li>- Home- more convenient, less burdensome, more personal and better support [42, 43] (+)</li> <li>- Home- barrier if patient lacks discipline and self-drive to exercise alone, and lack initial motivation to start PA alone in home [45] (-)</li> <li>- Hospital- keep medical appointments distinct from home life [43] (+)</li> <li>- Flexibility for venue- potential for different locations (voluntarily choose home) or virtual sessions [42] (+)</li> </ul>	<ul style="list-style-type: none"> <li>- Venue preference for PA (by % of patients): (+ &amp; -) <ul style="list-style-type: none"> <li>o Home: 20% [28], 24% [27], 67% [25], 100% [24] (Patients were more likely to prefer home if they were female, illiterate, not college educated, not undergone surgery or RT) [30]</li> <li>o Community centre or gym: 17% [27], 29% [28], (&lt; 70 years and those with higher incomes preferred to exercise at gym) [28]</li> <li>o Outdoors: 19% [27], 54% [30]</li> <li>o Cancer centre or hospital:</li> </ul> </li> </ul>

		<ul style="list-style-type: none"> <li>17% [28], 27% [27] <ul style="list-style-type: none"> <li>o No preference: 25% [28]</li> </ul> </li> <li>- Venue preference for PA counselling: community 9%, home 16%, cancer centre 36%, no preference 39% [30]</li> </ul>
<b>Access</b>	<ul style="list-style-type: none"> <li>- Transportation problems: inability to drive following surgery and potential difficulties with inclement weather, not accessing resources as feel other patients need it more [39, 42] (-)</li> <li>- Financial constraints [42] (-)</li> </ul>	<ul style="list-style-type: none"> <li>- Transportation: lack of transportation [23] and distance to home [25] (-), access to free parking [23] (+)</li> <li>- Better land-use mix access (i.e. access to shopping centres) [29] (+)</li> </ul> <p><i>Services (data from HCPs) #</i></p> <ul style="list-style-type: none"> <li>- Lack of rehab services: 39% of MDT felt rehabilitation services adequate [33]; long waiting lists for rehabilitation [33]; shortage of allied health staff [33]; 72% of physiotherapists reported &lt;25% patients referred to PRP on discharge [32]; PRP facilities not taking patients without COPD [32] (-)</li> <li>- Lack of knowledge of HCP: <ul style="list-style-type: none"> <li>o Services available (29% of MDT) [33]</li> <li>o Lack of perception patients do not want rehab (22% of MDT) [33] (-)</li> <li>o Lack of understanding of benefits [33] (-)</li> </ul> </li> </ul>
<b>Format</b>	<p><i>Group training</i></p> <ul style="list-style-type: none"> <li>- Promotes social engagement/benefits (by exercising with people with similar circumstance) [36, 43, 45] (+)</li> <li>- Promotes adherence due to the belief that the other patients expect you to turn up [45] (+)</li> <li>- Preference for mix gender groups [45] (+)</li> <li>- Use of music [36] (+)</li> <li>- Dislike talking to other patients in a group environment [43] (-)</li> </ul> <p><i>Type of exercise</i></p> <ul style="list-style-type: none"> <li>- Individualized- target intervention to specific problems such as breathlessness and modification for comorbidities [42] (+)</li> <li>- Something the patient is interested in and enjoys [43] (+)</li> <li>- Preference for structured and supervised exercise [45] (+)</li> </ul>	<p><i>Group training</i></p> <ul style="list-style-type: none"> <li>- Preference for PA (by % of patients): (+ &amp; -) <ul style="list-style-type: none"> <li>o Group: 19% [28], 29% [27]</li> <li>o 1-2 patients with cancer: 17% [27]</li> <li>o Alone: 22% [28], 26% [27], 44% [30], 49% [25]</li> <li>o No preference: 24% [27], 49%, [28]</li> <li>o Family: 5% [28]</li> </ul> </li> </ul> <p><i>Type of exercise (by % of patients): (+ &amp; -)</i></p> <ul style="list-style-type: none"> <li>- Preference for intensity of PA: <ul style="list-style-type: none"> <li>o Light: 36% [27], 39% [28], (57% felt capable) [25]</li> <li>o Moderate: 44% [28], 54% [30], 62% [27], (38% felt capable) [25]</li> </ul> </li> <li>- Walking as main type: 42% [28], 79% [27], 80% [25], 89% [30]</li> <li>- Recreational exercises: 94% [27], 96% [30]</li> </ul>

<ul style="list-style-type: none"> <li>- Offer a shortened trial [42] (+)</li> <li>- Outside of the supervised exercise setting patients prefer to do activities similar to those they did before their illness [45] (+)</li> <li>- Preference for usual activities over formal exercise programs [44] (+)</li> <li>- Walking preferred form of activity [44] (+)</li> <li>- Preference for activities that require the patients to focus continually on strategy and technique to achieving the goal of distraction (rather than activities such as cycling or walking) [24, 37] (+)</li> </ul> <p><i>Supervision</i></p> <ul style="list-style-type: none"> <li>- Provides a sense of security, leadership and motivation [36] (+)</li> <li>- Ability to be monitored and progressed [36, 38] (+)</li> </ul> <p><i>Virtual monitoring and prescription</i></p> <ul style="list-style-type: none"> <li>- HCPs expect that telemonitoring could be useful for specific rehabilitation goals [38] (+)<sup>#</sup></li> <li>- HCPs believe telerehabilitation is good strategy for provision of relevant information but needs supervision [38] (+ &amp; -)<sup>#</sup></li> <li>- Patients believe that supervision during telerehabilitation is important to ensure that exercises are performed correctly [38] (+)</li> <li>- Patients and HCPs both believe that online rehab requires motivation of patients to read the information and to exercise at home [38] (-)<sup>#</sup></li> <li>- Technical challenges for example ability to use a DVD [42] (-)</li> </ul>	<ul style="list-style-type: none"> <li>- Same exercises: 39% [27], 56% [30]</li> <li>- Different exercises: 61% [27]</li> <li>- Variety prevent boredom [24], fun/engaging 18% [25]</li> </ul> <p>Physiotherapists: 93% provide walking exercises following surgery, and in most facilities (88%) it was commenced as part of an early mobility program by physiotherapist [32]</p> <p><i>Supervision</i></p> <ul style="list-style-type: none"> <li>- Access to “coaching” was considered to be an important facilitator to promote attendance by 11% of patients [23]</li> <li>- Preference for supervision (by % of patients): (+ &amp; -) <ul style="list-style-type: none"> <li>o Yes: 62% [27], 85% [21] (64% supervised in gym and 36% at home) [21]</li> <li>o No: 64% [30] (&lt;65 years preferred unsupervised) [30]</li> </ul> </li> </ul>
<p><b>Convenience</b></p> <ul style="list-style-type: none"> <li>- Fitting the exercise into daily routine [41, 43] (+)</li> <li>- Flexibility of time of exercise session [42] (+)</li> <li>- Reminders to exercise [42] (+)</li> </ul>	<ul style="list-style-type: none"> <li>- Duration of PA program: no consensus [25]</li> <li>- Hours: flexibility (facilitator to participation 16% of patients) [25], 16% [23] and 93% [30] preferred a flexible exercise program (+)</li> <li>- Time of day: 53% [30] and 56% [27] patients preferred to exercise in the morning and 32% had no preference [27]. Patients with co-morbidities vs those with no comorbidities were more likely to prefer exercising in the morning [30] (+ &amp; -)</li> <li>- Scheduled program favoured by 71% of patients [27] (+)</li> </ul>

<b>Time</b>	<ul style="list-style-type: none"> <li>- Lack of time due to tests, medical appointments and work [36, 45] (-)</li> <li>- Time commitment required [42] (-)</li> </ul>	<ul style="list-style-type: none"> <li>- Lack of time due to work commitments [23], family matters [23] (-)</li> <li>- Time commitment required [23] (-)</li> </ul>
<b>Timing of exercise</b>	<ul style="list-style-type: none"> <li>- Not preferred at diagnosis or during treatment due to time commitment required of patients and carers, feeling of being overwhelmed and high symptoms [43] (-)</li> <li>- Not responsive to information given at times the patient perceives to be inappropriate (i.e., when not experiencing symptoms, when too ill to take information on board, when waiting for treatment/appointments, or when they were concerned about other issues) [43] (-)</li> <li>- Overwhelming to consider participation (in mindfulness treatment) at diagnosis [42] (-)</li> </ul>	<p><i>Commencement of exercise</i></p> <ul style="list-style-type: none"> <li>- Preference for timing of program (by % of patients): (+ &amp; -) <ul style="list-style-type: none"> <li>o Before treatment: 22% [30], 26% [27], 60% [28]</li> <li>o During treatment: 14% [30], 17% [27]</li> <li>o Immediately post treatment: 10% [30], 14% [28], 23% [27]</li> <li>o 3-6 months post treatment: 13% [28], 22% [30], 23% [27], 23% [30]</li> <li>o No preference: 11% [30], 59% [25]</li> </ul> </li> <li>- Most patients who had thoracic surgery preferred to start an exercise program during adjuvant treatment (43%) vs 11% of patients who did not have surgery. Most (57%) who did not have surgery preferred to start their exercise after completing treatment (+/-) [27]</li> <li>- Preference for timing of counselling (by % of patients): (+ &amp; -) <ul style="list-style-type: none"> <li>o Before treatment: 14% [30], 22% [27], 68% [28]</li> <li>o During treatment: 17% [30], 28% [27]</li> <li>o Immediately post treatment: 14% [30], 23% [28], 28% [27]</li> <li>o 3-6 months post treatment: 12% [27], 21% [30]</li> <li>o No preference: 25% [30]</li> </ul> </li> <li>- Physiotherapists: 91% commence physiotherapy on first post-operatively day, 9% on the day of surgery [32] (-) #</li> </ul>
<b>Weather</b>	<ul style="list-style-type: none"> <li>- Winter weather- fear of falling, the effects of cold on breathing, dislike of cold [44] (-)</li> <li>- Low resilience to finding alternative forms of PA when they cannot perform usual activities due to external variables such as weather or when the environment is not adaptable to their condition [37] (-)</li> </ul>	<ul style="list-style-type: none"> <li>- Bad weather [25] (-)</li> </ul>
<b>Delivery of information</b>	<ul style="list-style-type: none"> <li>- Rely almost exclusively on verbal information provided by their doctor</li> </ul>	<ul style="list-style-type: none"> <li>- Interest in receiving exercise counselling (by % of patients): (+ &amp;</li> </ul>

<p>on information about their diagnosis, management and prognosis [39] (+ &amp; -)</p> <ul style="list-style-type: none"> <li>- Physician encouragement or prescription of exercise[44] (+)</li> <li>- Patient would be comfortable discussing PA/ exercise with their oncologists but few had done so[44] (+ &amp; -)</li> <li>- Would seek advice from either a physician or a physiotherapist [44] (+)</li> <li>- Direction from a physiotherapist was viewed as potentially beneficial, generally for support rather than to build strength and stamina. Opportunity for guidance about exercise was viewed as a benefit [44] (+)</li> <li>- Patients believe they may not be at a level of functional disability needing assistance from physiotherapist or nurse and or uncertain about its benefits [44] (-)</li> <li>- Contradictory advice from different HCPs [43] (-)</li> <li>- Preferred same physiotherapy trainers at each session not different ones [36] (+ &amp; -)</li> </ul>	<p>-)</p> <ul style="list-style-type: none"> <li>o Yes: 23% [27], 63% [28], 85% [30]</li> <li>o No: 42% [27]</li> <li>o Maybe: 35% [27]</li> </ul> <ul style="list-style-type: none"> <li>- Preference of HCPs to deliver advice (by % of patients): (+ &amp; -) <ul style="list-style-type: none"> <li>o Medical doctor: 28% [30], 80% [26] (&lt;70 years and higher income associated with this choice) [28]</li> <li>o Nurse: 22% [30]</li> <li>o Exercise specialist: 21% [30], 59% [27] (higher % preferred exercise specialist if they had attained a college education) [30]</li> <li>o No preference: 49% [30]</li> </ul> </li> <li>- Preference for method of delivery (by % of patients): (+ &amp; -) <ul style="list-style-type: none"> <li>o In person: 48% [30], 87% [27], 95% [28], (this choice associated with being employed, college educated, and lack of comorbidities) [30]</li> <li>o Brochure: 21% [30]</li> </ul> </li> <li>- Previous discussion with HCP about PA for 65%[26]: 70% of discussions initiated by the HCP; 49% did not receive advice to change their level of PA despite not meeting PA guidelines; less frequent discussions during cancer treatment (51%); male patients and higher income= more likely to have discussions regarding PA [26]</li> <li>- Physiotherapists: 44% routinely provide pre-operative education, pre-operative education initiated by surgeon referral 9% of the time [32] (-)<sup>#</sup></li> </ul>
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*Abbreviations: ADLs, activities of daily living; HCPs, health care providers; mod, moderate; PA, physical activity; PRP, pulmonary rehabilitation program; rehab; rehabilitation; SOB, shortness of breath.*

*(+) = enabler to physical activity or exercise*

*(-) = barrier to physical activity of exercise*

*Unless otherwise stated (and marked with <sup>#</sup>) data are from patients with lung cancer not carers or HCPs*

## Supplementary files

### Online supplementary table E1: Search strategy

Database	Search fields	Search terms
Medline	Title, abstract,	1. "lung" AND "cancer"
CINAHL	keywords, topic	2. "physical activity" OR "exercise" OR
EMBASE		"rehabilitation" OR "physiotherapy" OR
Scopus		"physical therapy" OR "physical function
Cochrane		3. "barrier*" OR "hinder*" OR "enabler*" OR
Library		"facilitat*" OR "preference" OR
		"determinant*" "culture" OR
		"implementation" OR "process evaluation"
		OR "quality assurance" OR "quality
		improvement" OR "clinical outcomes" OR
		"focus group" OR "qualitative"
		4. #1 and #2 and #3

Abbreviations: CINAHL, Cumulative Index to Nursing and Allied Health Literature; EMBASE, the Excerpta Medica Database.

### Online supplementary table E2: Study aims and methodology

First author, year	Primary aims	Data collection of barriers and enablers to PA	
Qualitative studies		Methodological approach	Qualitative data collection
Brown 2015[39]	To address the supportive care needs and preferences of lung ca patients	Grounded theory	Semi-structured interviews, 33-85 min duration
Kuijpers 2015[38]	To explore the expectations of an interactive portal among ca survivors and HCPs	Inductive content analysis	9 focus groups: 2 with lung ca patients, 3 with breast ca patients and 4 with HCPs
Mas 2015[37]	To identify barriers to and facilitators of PA in lung ca patients	Thematic analysis	Semi-structured interviews
Missel 2015[36]	To explore operable lung ca patient experiences with an exercise intervention from a longitudinal perspective according to patient motivation and patient perceived benefits and barriers of exercise	Ricoeur's theory of interpretation	Semi-structured interviews, 25-90 min duration

Hoffman 2014[40]	To identify the postsurgical NSCLC patients' unmet supportive care needs during transition from hospital to home and through recovery after participating in a 16-week exercise intervention	Content analysis	Focus group, 2 hours duration
Lehto 2013[42]	To obtain lung ca patient perceptions of a mindfulness-based intervention	NR	Focus group, 2 hours duration
Maddocks 2013[41]	To determine the acceptability of NMES of the quadriceps to patients with NSCLC used alongside palliative chemo and to explore aspects of safety and efficacy of NMES in this setting	Inductive thematic analysis	Semi-structured interviews
Adamsen 2012[45]	To explore feasibility, health benefits and barriers of exercise in former sedentary patients with advanced stage lung ca undergoing chemo	Thematic analysis	Semi-structured interviews (15 patients, 45–60 min duration) and one focus group (8 patients, 2 hours duration)
Cheville 2012[44]	To characterize the beliefs of patients with late-stage disease regarding exercise, its relationship to their symptoms, and their clinicians' roles in providing related counselling	Content analysis	Semi-structured interviews, 20-50 min duration
Ellis 2012[43]	To identify the views of patients with lung ca and their informal caregivers on the desirable components of a novel non pharmacological intervention for the management of the symptom cluster of cough, breathlessness, and fatigue, and their needs and preferences regarding uptake and delivery of the intervention	Framework analysis	Semi-structured interviews, 30-90 min duration
Jones 2009[46]	To explore the experience of follow up for patients with lung cancer after surgery and to determine what, if any, additional support would be most helpful	Thematic analysis	Semi-structured interviews, 45 min duration
<b>Quantitative studies</b>		<b>Outcome measures</b>	

Kartolo 2016[25]	To investigate the motivation, ability, preferences, and perceived potential facilitating factors/barriers of patients with inoperable metastatic lung ca towards exercise programmes. To explore the possible relationships between patients' motivation and exercise programmes.	Bespoke designed survey
Leach 2015[27]	To explore the exercise counselling and programming preferences of lung ca survivors. To examine the association of exercise before diagnosis, during treatment and after treatment on HRQoL.	Exercise preferences: Bespoke designed survey PA levels: Modified version of the Godin Leisure Time Exercise Questionnaire HRQoL: FACT-L, CRDQ
Philip 2015[26]	To describe early stage lung ca survivors' self-reported discussion of PA with HCP. To examine the association between sociodemographic, disease, and health behaviour variables and discussion characteristics.	PA levels: Modified version of the GLTEQ Discussion of PA: Bespoke designed survey
Granger 2014[29]	To objectively measure level of PA. To compare motivation to exercise between individuals with NSCLC and healthy individuals. To explore the relationships between PA and (a) levels of depression, (b) motivation to exercise, and (c) environmental barriers to PA.	Motivation for exercise: Behavioural Regulation of Exercise Questionnaire v2 Environmental barriers to PA: Neighbourhood Environment Walkability Scale – Australian Version
Philip 2014[28]	To establish survivors' preferences concerning engagement in PA and receiving PA advice in the context of their ca care	PA levels: modified version of the GLTEQ PA preferences: Bespoke designed survey
Anderson 2013[22]	To investigate the impact of a modified exercise intervention on adherence	HRQoL: EORTC QLQ-30 and QLQ-LC13
Cavalheri 2013[32]	To describe current physiotherapy practice patterns in the preoperative and postoperative management of patients who undergo surgical resection for lung ca	Bespoke designed survey

Hoffman 2013[24]	To evaluate the feasibility, acceptability, safety, and changes in study end points of a home-based exercise intervention to enhance perceived self-efficacy for ca-related fatigue self-management for persons after thoracotomy for NSCLC transitioning from hospital to home.	Feasibility: Analysis of recruitment, adherence, retention and adverse events Acceptability questionnaires: Brief Fatigue Inventory, Perceived Self-efficacy for Fatigue Self-management Instrument, Self-efficacy for Walking Duration Instrument, Activities – Specific Balance Confidence Scale, Daily Diary
Lebel 2013[31]	To document the positive health changes that survivors of head and neck or lung ca adopt after diagnosis. To examine the ways in which behavioural self-blame and stigma relate to PHCs.	Positive health changes: Bespoke designed survey Behavioural self-blame: Bespoke designed survey Stigma: Subscale from the Explanatory Model Interview Catalogue
Lin 2013[30]	To investigate lung ca patients' PA preferences and relevant contributing factors, in order to develop individualized intervention strategies to fit their needs	PA preferences: Bespoke designed survey Social support for the Physical Activity Scale: "perceived social support specific to health-related exercise behaviours scale" PA Self-efficacy Scale: Bespoke designed survey
Peddle-McIntyre 2013[21]	To examine the effects of a 10-week supervised progressive resistance exercise training program on lung ca survivors' motivational outcomes based on the Theory of Planned Behaviour	Bespoke designed survey
Nwosu 2012[33]	To explore perceptions of palliative care and respiratory MDT members about the role of rehabilitation for lung ca patients. To examine the pattern of referral for lung ca patients to rehabilitation services. To highlight the barriers that prevent the referral of lung ca patients to rehabilitation services.	Bespoke designed survey

Coups 2009[34]	To investigate correlates of PA in lung ca	PA self-efficacy: Barriers Self-efficacy Scale PA outcome expectations: Exercise Decision Balance Questionnaire Perceived social support: Social Support for Exercise Scale Perceptions of environmental support: Environmental Support for Physical Activity Long Questionnaire PA: Modified GLTEQ Past engagement in leisurely walking in previous month: Yale Physical Activity Survey
Peddle 2009[23]	To examine the demographic, medical, and social-cognitive correlates of adherence to a pre-surgical exercise training intervention in patients awaiting surgery for suspected malignant lung lesions	Perceived behavioural control and self-efficacy; Attitude; Subjective norm; Intention: Bespoke designed survey
Clark 2008[35]	To examine the relationship between motivational readiness for PA and HRQoL in long-term lung ca survivors	Stage of change for physical activity level: Four-item measure HRQoL: Linear analogue self-assessment across 6 domains

*Abbreviations: ca, cancer; chemo, chemotherapy; CRDQ, Chronic Respiratory Disease Questionnaire; EORTC QLQ C30, European Organisation for the Research and Treatment of Cancer questionnaire; FACT-L, Functional Assessment of Cancer Therapy – Lung; GLTEQ, Godin Leisure Time Exercise Questionnaire; HCPs, health care providers; min, minutes; NMES, neuromuscular electrical stimulation; NR, not reported; NSCLC, non-small cell lung cancer; PA, physical activity; QLQ-LC13, European Organisation for the Research and Treatment of Cancer questionnaire-lung cancer-specific questionnaire.*

### Online supplementary table E3: Risk of bias in primary studies

First author, yr	Risk of bias assessment			Total score
	<i>Newcastle–Ottawa Quality Assessment Scale</i> [16]			
Case series	<i>Selection (0-3)<sup>#</sup></i>	<i>Comparability (0-2)</i>	<i>Outcome (0-3)</i>	(/8)
Andersen 2013[22]	1	-	2	3
Hoffman 2013[24]	2	-	2	4
Peddle-McIntyre 2013[21]	2	-	3	5
Peddle 2009[23]	2	-	3	5
<b>Mean (SD)</b>	<b>1.7 ± 0.5</b>	<b>0</b>	<b>2.5 ± 0.6</b>	<b>4.2 ± 1.0</b>
Cross-sectional	<i>Agency for Healthcare Research and Quality Methodology Checklist</i> [17]			(/11)
Kartolo 2016[25]				7
Leach 2015[27]				8
Phillip 2015[26]				6
Granger 2014[29]				11
Phillip 2014[28]				7
Cavalheri 2013[32]				8
Lebel 2013[31]				8
Lin 2013[30]				8
Nwosu 2012[33]				10
Coups 2009[34]				8
Clark 2008[35]				9
<b>Mean (SD)</b>				<b>8.2 ± 1.4</b>
<i>COREQ checklist</i> [18]				
Qualitative	<i>Team &amp; reflexivity (/8)</i>	<i>Study design (/15)</i>	<i>Analysis &amp; findings(/9)</i>	(/32)
Brown 2015[39]	0	10	7	17
Kujpers 2015[38]	1	7	7	15
Mas 2015[37]	3	11	6	20
Missel 2015[36]	0	11	5	16
Hoffman 2014[40]	1	10	8	19
Lehto 2013[42]	1	7	7	15
Maddocks 2013[41]	0	9	2	11
Adamsen 2012[45]	2	8	6	16
Cheville 2012[44]	2	12	6	20
Ellis 2012[43]	1	9	7	17
Jones 2009[46]	0	10	5	15
<b>Mean (SD)</b>	<b>1.0 ± 1.0</b>	<b>9.4 ± 1.6</b>	<b>6.0 ± 1.6</b>	<b>16.4 ± 2.6</b>

Abbreviations: COREQ, Consolidated criteria for reporting qualitative research; SD, standard deviation; yr, year.

\* Criteria satisfied - Criteria not satisfied, high risk of bias

<sup>#</sup> Domain 1 (selection) scored out of 3 not the traditional 4 points because one item from this domain was deemed not appropriate for this review (demonstration that outcome of interest was not present at start of study)