

# Translating the Interplay of Cognition and Physical Performance in COPD and Interstitial Lung Disease

## Meeting Report and Literature Review



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**TOPIC IMPORTANCE:** Cognitive and physical limitations are common in individuals with chronic lung diseases, but their interactions with physical function and activities of daily living are not well characterized. Understanding these interactions and potential contributors may provide insights on disability and enable more tailored rehabilitation strategies.

**REVIEW FINDINGS:** This review summarizes a 2-day meeting of patient partners, clinicians, researchers, and lung associations to discuss the interplay between cognitive and physical function in people with chronic lung diseases. This report covers four areas: (1) cognitive-physical limitations in patients with chronic lung diseases; (2) cognitive assessments; (3) strategies to optimize cognition and motor control; and (4) future research directions. Cognitive and physical impairments have multiple effects on quality of life and daily function. Meeting participants acknowledged the need for a standardized cognitive assessment to complement physical assessments in patients with chronic lung diseases. Dyspnea, fatigue, and age were recognized as important contributors to cognition that can affect motor control and daily physical function. Pulmonary rehabilitation was highlighted as a multidisciplinary strategy that may improve respiratory and limb motor control through neuroplasticity and has the potential to improve physical function and quality of life.

**SUMMARY:** There was consensus that cognitive function and the cognitive interference of dyspnea in people with chronic lung diseases contribute to motor control impairments that can negatively affect daily function, which may be improved with pulmonary rehabilitation. The meeting generated several key research questions related to cognitive-physical interactions in individuals with chronic lung diseases. CHEST 2024; 166(4):721-732

**KEY WORDS:** cognition; exercise; lung disease, interstitial; lung disease, obstructive; rehabilitation

**ABBREVIATIONS:** ADL = activities of daily living; HRQOL = health-related quality of life; ILD = interstitial lung disease; IMT = inspiratory muscle training; PR = pulmonary rehabilitation

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COPD and interstitial lung disease (ILD) (termed chronic lung diseases in this report) have high prevalence, mortality, multimorbidity, and systemic effects beyond lung pathophysiology.<sup>1,2</sup> Common extraparenchymal manifestations that can affect health management are cognitive and physical impairments<sup>2,3</sup> that can significantly diminish daily function and health-related quality of life (HRQOL).<sup>4</sup> These impairments also increase the risk of hospitalizations, disability, and death in patients with chronic lung diseases.<sup>5</sup>

Cognitive impairment in chronic lung diseases<sup>6,7</sup> can impede memory, concentration, learning, and visual-

motor responses.<sup>8</sup> Although better described in COPD than in ILD, underlying mechanisms have been attributed to hypoxia, hypercapnia, inflammation, cerebrovascular changes,<sup>8</sup> and neural tissue hypoxemia.<sup>9</sup> Aging is recognized as an important contributor to cognitive decline, specifically in the domains of memory, processing speed, and executive function in healthy individuals, and is more pronounced in those with chronic lung diseases.<sup>10,11</sup> Several areas of the brain can be affected, but a key region compromised in patients with COPD is the prefrontal cortex, which is important for executive function (ie, attention, strategizing) and affective processing.<sup>12</sup> Decrements in physical tasks that require executive function have been shown in patients with COPD.<sup>12,13</sup> Moreover, decreased executive function can also limit goal-directed behaviors and comprehension of therapeutic regimens, predisposing to delays seeking medical attention.<sup>14</sup>

Daily physical function is influenced by motor control, which is the ability of the brain to provide coordinated purposeful movement. According to motor control theory,<sup>15</sup> accurate movement is influenced by cognition, sensory perception, and their interaction with several body systems (ie, muscle, respiratory, vision). Although the synergistic actions of these systems enable purposeful movement, disruption of one or more systems will diminish motor control. Dyspnea, a predominant symptom in chronic lung diseases, may impair movement and daily activities, not only due to its aversive nature but also through interference with cognitive processing, and thus motor control of respiratory and limb muscles.<sup>9</sup> Several other factors can limit cognition and physical performance such as mood, fatigue, sleep, and motivation.<sup>16,17</sup>

Most daily activities require multitasking, the ability to carry out two or more tasks simultaneously. Dual-tasking is an experimental paradigm that assesses decrements in performance while doing two things simultaneously. It has been widely used in older adults and those with neurologic disorders (ie, stroke).<sup>18,19</sup> People with COPD walk more slowly in a dual-task paradigm compared with solely walking, suggesting that they prioritize balance, designated a “posture-first” strategy.<sup>12,20</sup> Cognitive interference or limitations in people with COPD may compromise multitasking during activities of daily living (ADLs), increasing risk for impaired balance and falls.<sup>21</sup> Although ADLs can be limited in those with ILD, cognitive limitations or dual-tasking have not been evaluated as contributing factors.<sup>22,23</sup> Even though exercise training in individuals with COPD and ILD can

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increase muscle strength and endurance,<sup>24</sup> motor learning approaches validated in other populations (ie, older adults, those with neurologic disorders)<sup>20,25</sup> could potentially improve motor control, coordination, and daily activities in people with chronic lung diseases. Thus, it is important to consider whether cognitive assessments and cognitive-motor training can be integrated into pulmonary rehabilitation (PR) management.

Given the increasing age, complexity, and prevalence of frailty in individuals with chronic lung diseases,<sup>26</sup> evaluation of cognition and physical function is becoming critically important in these patient

populations. Understanding the interplay between cognition and physical function in individuals with COPD and ILD will allow development of novel rehabilitation strategies, provide a better understanding of patient compliance, inform key research questions, and enhance delivery of patient care. Thus, the planning and dissemination meeting objectives were to provide a forum for knowledge exchange on mechanistic underpinnings related to motor control in those with chronic lung diseases and to describe key rehabilitation strategies to address cognitive-physical limitations, including future research priorities.

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## Methods

A 2-day virtual meeting, funded by the Canadian Institutes of Health Research, was held in November 2022. Thirty-eight patient partners, clinicians, and researchers from diverse areas (ie, family practice, nursing, palliative care, physical therapy, physiology, psychology, and pulmonology) and geographic locations (Belgium, Canada, the Netherlands, and the United States) took part in the meeting.

A premeeting survey helped to identify interests, expertise, and gaps. Evidence from a previous scoping review helped with meeting planning to identify topics related to the impact of cognition on physical function in individuals with chronic lung diseases.<sup>21</sup> The proposed agenda was further refined during a 1.5 h planning meeting. Pre-readings, identified by the speakers, were circulated prior to the 2-day main meeting to enhance participation.

Five patient partners contributed to a video presentation that opened the 2-day meeting. They addressed how cognitive and physical limitations influenced their day-to-day lives (details are presented in [e-Appendix 1](#)). The main meeting consisted of two 5 h sessions that were held 1 week apart ([e-Appendix 2](#)).

Thirteen presentations were given in four major areas: (1) cognitive-physical limitations in patients with chronic lung diseases; (2) cognitive assessments; (3) strategies to optimize cognition and motor control; and (4) future research directions. Both days culminated in 1.5 h breakout sessions to discuss patient priorities, clinical strategies, impactful research paradigms, and implementation approaches. Breakout discussions were transcribed and speakers' PowerPoint presentations were referred to following the meeting to confirm content for the current report.

Representatives from the British Columbia Lung Foundation, the Lung Health Foundation in Ontario, and the Canadian Lung Association attended the meeting and highlighted resources available for patients. To further corroborate literature presented at the meeting, a librarian conducted an updated literature review with MEDLINE using key concepts of COPD or ILD and cognitive function from inception (1946) to April 5, 2024 ([e-Appendix 3](#)). Related activities during and following the 2-day meeting were reviewed by the University of Toronto Ethics Board and deemed to be exempt from requiring ethics approval.

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## Results

### *Cognitive Limitations and Interference With Physical Function*

The first part of the meeting focused on evidence of cognitive limitations in people living with chronic lung diseases that addressed patients' needs, especially as they pertain to health management and the cognitive load of

dyspnea. A quote from one patient partner captures the essence of a major issue addressed:

*“At one time I was very good at it (multitasking). But now it's kind of one thing at a time and probably because I don't want to fall. ... So multitasking has changed, I think age, I think breathing...hip replacements ... things just change as you get up there...”*

More excerpts from the patient partner presentation are provided in [e-Appendix 1](#).

Meeting presentations and the literature review supported the idea that the pathophysiology of cognitive impairments in patients with COPD is multifactorial.<sup>4</sup> Hypoxemia can induce neural damage and limit oxygen-dependent transmitters. Other potential cognitive contributors are systemic inflammation, oxidative stress, and microvascular injury.<sup>4,7</sup> Furthermore, the impact of COPD severity on cognitive impairment remains unclear.<sup>3,4,9</sup> One cross-sectional study during the meeting highlighted that cognitive impairment was not related to COPD severity measures in a cross-sectional study of 183 patients with COPD<sup>27</sup> and a similar lack of association was described in a study of 1,202 individuals with COPD.<sup>9</sup> Moreover, prevalence of cognitive dysfunction in patients with COPD ranges from 10% to 61%.<sup>4</sup> Meeting attendees speculated whether this reflects the sensitivity of the tests for different cognitive domains.

Although ILD and COPD are often considered together, several stakeholders emphasized the distinct nature of these two conditions. Of note, no neurobiological model of cognitive impairments in ILD has been defined, but cognitive impairment is considered to be multifactorial with several contributors similar to those of COPD.<sup>8,9</sup> Cognitive impairment in individuals with ILD has been ascribed to disease severity, dyspnea, inflammation, sleep apnea, and fatigue.<sup>6,28</sup> Fatigue, which can affect > 50% of individuals with COPD and ILD, has been shown to be associated with impairments in cognitive function.<sup>17,29</sup> The underlying etiology and evidence of cognitive limitations in ILD are less definitive compared with those of COPD, and further study is needed to examine differences between these two conditions.

Two presentations highlighted the attributes of dyspnea, a universal multifaceted symptom in chronic lung diseases, and its impact on cognition and physical function. Dyspnea activates widespread brain networks that contribute to motor, affective, and cognitive processing.<sup>30</sup> Consequently, physical activity and cognition can be limited by exceeding the shared networks for motor control and dyspnea processing. The respiratory muscle “tension-volume” disparity due to hyperinflation in COPD<sup>31</sup> and decreased pulmonary compliance in ILD<sup>32</sup> requires greater neural activation for respiratory muscle recruitment,<sup>33</sup> in addition to affect-related brain networks to process dyspnea.<sup>30</sup> This cortical activation can compete with the limited

cognitive capacity available for motor control of limb muscles. The interference of respiratory muscle loading with associated dyspnea results in decrements of cognition and motor control in healthy people,<sup>30</sup> and evidence is emerging in individuals with COPD.<sup>21</sup>

Subsequent presentations highlighted how cognitive limitations can affect physical function in people living with COPD and ILD, although this is less well described in those living with ILD.<sup>8,34</sup> Cognitive impairment has been associated with worse exercise capacity in COPD and ILD<sup>35,36</sup>; however, the evidence is inconsistent and may be affected by age and educational levels.<sup>21</sup> Moreover, cognition seems to be more closely related to balance in COPD. Although dual-task paradigms are not widely used in patients with chronic lung diseases, deficits in walking and balance occur when performed with a concurrent cognitive task in people with COPD. This has been attributed in part to a loss of neural efficiency during gait, also termed automaticity.<sup>37</sup> Characterizing dual-task decrements of motor control may facilitate identification of rehabilitation strategies to improve daily activities.

Cognitive and motor skills can be organized in a hierarchy according to the selective integration of sensory input ([Fig 1](#)).<sup>38,39</sup> Notably, many ADLs call upon a high level of cognitive-motor processing. How cognitive limitations affect physical daily activities can be exemplified by the self-administration of inhaled medications. This task requires patients to comprehend complex instructions, plan the task, and to perform coordinated upper extremity and chest wall movements, with cognitive impairment predictive of poor inhaler technique.<sup>40</sup>

### *Evaluation of Cognition in Chronic Lung Diseases*

Several cognitive assessments have been used to evaluate individuals with chronic lung diseases. These range from screening questionnaires (ie, Montreal Cognitive Assessment) to more comprehensive neuropsychological testing batteries.<sup>21</sup> Most studies assessed patients with COPD, and only a few evaluated those with ILD.<sup>6,36</sup> Several used cognitive-physical dual-tasking that incorporated backward subtraction, backward spelling, and verbal fluency tasks.<sup>21</sup>

[Table 1](#)<sup>12,21,41-46</sup> highlights many of the cognitive assessments that have been used to evaluate people with COPD or ILD and the associated cognitive domains evaluated, time required for test completion, special training, and test limitations. A well-defined



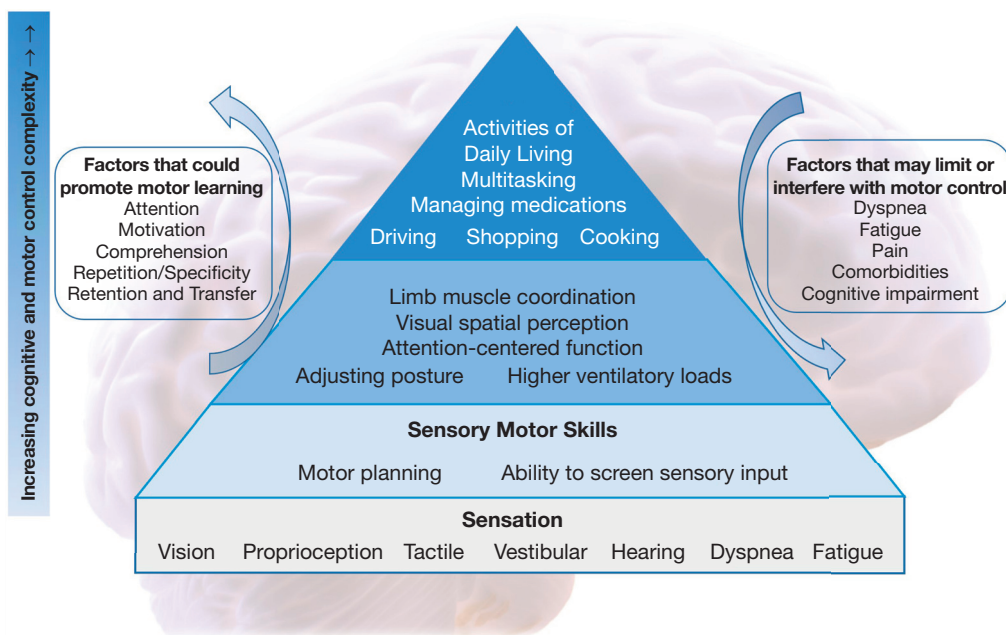


Figure 1 – Conceptual model of cognitive and motor control interactions affecting activities of daily living in people with chronic lung disease. Motor and cognitive skills can be considered as a hierarchy. Motor planning requires the selective integration of sensory neural input. Many activities of daily living require very complex cognition and motor control. The ability to perform activities of daily living may be improved through motor learning training strategies. This requires attention, motivation, and comprehension to learn a skilled task and then repetitive practice until the movement or complex action can be performed automatically. Factors such as dyspnea, fatigue, and pain may interfere with the ability to practice or move in a particular manner. Comorbidities can interfere with the desired motor action, whereas cognitive impairment could interfere with comprehension and retention. Conceptual diagram of motor learning pyramid and cognitive interplay adapted from Williams and Shellenberger<sup>38</sup> and Cleutjens et al.<sup>39</sup>

neuropsychological approach in selecting tests to evaluate specific cognitive domains has not been developed. Furthermore, there is no evidence to support cognitive screening using a single-item question in chronic lung diseases, as has been applied in community-dwelling adults.<sup>47</sup> Thus, the meeting participants agreed that a standardized cognitive battery in chronic lung diseases should be developed in future research that may help evaluate cognitive limitations and guide treatment recommendations.

### Approaches to Optimize Cognitive Processing and Motor Control During Daily Activities

Several presentations highlighted how rehabilitation strategies could be used to improve motor control and cognitive outcomes. To date, physical training for patients with chronic lung diseases has been shown to increase exercise capacity,<sup>48,49</sup> with some evidence of improved balance in patients with COPD.<sup>50</sup> Exercise training can modify neuroplasticity through direct effects on brain structure and function, and indirectly through physiological adaptations and improvements in psychological well-being.<sup>51</sup> Although well described in healthy adults,<sup>52</sup> investigations on improving the cognitive and motor control of physical activities in

patients living with chronic lung diseases are in the early stages.<sup>53</sup>

Limited evidence was presented on improvement in cognition from PR in individuals with COPD. A systematic review summarized seven reports on cognitive outcomes from exercise training and showed mixed but generally favorable results.<sup>53</sup> Domains often impaired in COPD, such as processing speed, attention, and executive function, responded positively to exercise. More recent studies also showed improvements in learning and memory, visuospatial abilities, language, and global function.<sup>54</sup> However, it is important to note that studies differed in experimental designs and, for the most part, did not apply comprehensive evaluations.<sup>53,54</sup> Although long-term adherence was challenging for most, participants who maintained exercise also showed persistent gains in both physical and cognitive function.<sup>55</sup>

A presentation highlighted the motor control of the respiratory muscles through evaluation of their timing and coordination using electromyography.<sup>56</sup> Whether cognitive processing is affected by inspiratory muscle training (IMT) in individuals with chronic lung diseases remains to be determined. Increased ventilatory efforts

TABLE 1 ] Cognitive and Dual Task Assessments in Chronic Lung Diseases

Cognitive Assessment/ Instrument	Brief Description of Assessment	Administration Time and Special Training	Limitations
<b>Cognitive screening instrument</b>			
Montreal Cognitive Assessment <sup>41</sup>	A cognitive screening tool designed to identify the presence of mild cognitive impairment. A score of > 26 of 30 is considered normal in the general population  <b>Cognitive domains:</b> Memory, language, executive function, visuospatial skills, calculation, abstraction, attention, concentration, and orientation	10 min  Training and certification are required	Consideration of educational level in those with lower/higher levels (floor and ceiling effects)  Cross-cultural limitations
<b>Executive function, processing speed, or verbal fluency</b>			
Trail Making Test (Part A and Part B) <sup>42</sup>	Part A: Accurately connect 25 numbers that have been randomly placed and encircled in a specific order. Part B: Connect 25 randomly placed numbers and encircled letters, following an alternating alphanumeric sequence (eg, number-letter-number-letter). Scoring is based on the time (seconds) taken to complete each section. A shorter time indicates better performance  <b>Cognitive domains:</b> Measures processing speed (Part A) and processing speed with cognitive switching, an aspect of executive function (Part B)	5 to 10 min  Public domain	Part B has limitations in detecting cognitive switching in those with slow processing or reduced fluency with the English alphabet
Verbal Fluency Test <sup>43</sup>	Evaluates the capacity to generate words starting with a particular letter (phonemic verbal fluency) or pertaining to a specific knowledge category (semantic verbal fluency). The total number of words named comprises the score  <b>Cognitive domains:</b> Measures verbal generativity and word access, with phonemic fluency particularly associated with frontal lobe generativity (an aspect of executive function)	Usually 60 s per trial (total of 5 min depending on how many trials administered)  No training required	Cultural and language factors  Slow processing speed or reduced language fluency may affect phonemic fluency and not reflect limitations in executive function
<b>Working memory, processing speed, attention, visual scanning, executive function</b>			
Digit Symbol Substitution Test <sup>44</sup>	Cognitive test that involves matching symbols to numbers with participants copying the symbol into spaces below a row of numbers. The score is calculated based on the number of correct symbols while timed  <b>Cognitive domains:</b> Measures psychomotor speed, attention, and visual scanning	90-120 s  No specialized training required Public domain	Lack of specificity in determining the precise cognitive domain that has been affected (eg, motor slowing vs psychomotor slowing)
Clock-Drawing Test <sup>45</sup>	Requires the individual to draw a clock  Free-drawn method: The individual is asked to draw a clock from their memory	No time limit  No training required	Not a sensitive instrument for subtle cognitive impairment

(Continued)

TABLE 1 ] (Continued)

Cognitive Assessment/ Instrument	Brief Description of Assessment	Administration Time and Special Training	Limitations
	<p>Pre-drawn method: The participant is given a circular outline of a clock and then asked to fill in the numbers on the clock face and/or to draw the clock hands at a fixed time</p> <p><b>Cognitive domains:</b> Measures planning, memory, visuospatial ability, neglect, attention, and symbolic representation</p>	Public domain and widely available	
Dual task (ie, backward spelling or counting) <sup>21</sup>	<p>Dual-task interference involves performing a cognitive task while doing a motor task</p> <p><b>Cognitive domains:</b> Attention, working memory</p> <p>Spelling backward: Example can include spelling a 5-letter word backward</p> <p>Backward counting: A cognitive task requiring counting backward from one number to another (ie, 50-1, 100-1). A point is given for each correct answer</p> <p><b>Cognitive domains:</b> Attention, memory, executive function</p>	<p>Spelling backward</p> <p>Less than 1 min</p> <p>The duration of counting backward is variable based on test</p> <p>No training required</p>	<p>Non-English-speaking individuals may find it difficult to spell English words backward</p> <p>May not provide a reliable measure of change over time</p>
Digit Span <sup>12</sup>	<p>The task involves asking participants to repeat a sequence of numbers that gradually increases in length</p> <p>Digit span forward: Participants are instructed to recall the numbers presented in the same order</p> <p>Digit span backward: Recall numbers in reverse order</p> <p>Total correct score determined by adding the number of correctly reported lists from both the forward span and the backward span</p> <p><b>Cognitive domains:</b> Working memory and attention</p>	<p>Varies depending on performance (approximately 1-3 min)</p> <p>No training required</p>	The presenter's pronunciation, including clarity, pitch, and rhythm, can affect the scores
Reasoning and problem solving			
Culture Fair Intelligence Test <sup>46</sup>	<p>Nonverbal skills that define a person's general intelligence minimizing sociocultural or environmental influence</p> <p>Forms A and B with 4 subtests: Series, classification, matrices, and condition.</p> <p>Each subtest is scored by counting the number of correct responses</p> <p><b>Cognitive domains:</b> Fluid intelligence, reasoning, and problem solving</p>	<p>Varies by tests used (approximately 12-18 min per section)</p> <p>No training required</p>	<p>Not widely used</p> <p>Long administration time</p>

require activation of the motor cortex to augment the neural drive that requires minimal cortical activation during quiet breathing.<sup>57</sup> In fact, a single trial of inspiratory threshold loading in healthy participants induces significant activation of prefrontal cortical regions, bilateral insula, and cerebellum.<sup>58</sup> This suggests that IMT has the potential to not only improve respiratory muscle strength and endurance but could induce motor learning and minimize cortical demands; this topic requires further study.

Cognition, dexterity, and coordination are recognized as requirements for effective delivery of inhaled medications,<sup>59</sup> although aspects of motor control training to improve this complex technique have not been addressed. In fact, proficiency of inhaler delivery has not improved for > 50 years.<sup>60</sup> One study reported that hand visual-motor coordination and fine motor control in patients with COPD were almost 2 SDs below normative values for the grooved pegboard test.<sup>61</sup> Other aspects of upper limb strength, endurance, and related daily activities are also limited in individuals with COPD but improve in response to arm exercise training<sup>62</sup> and with inhaler technique practice, even in those with cognitive limitations.<sup>63</sup>

Given that many daily activities require a high level of cognitive complexity (Fig 1), motor learning should target specific activity tasks. Although health care practitioners can be reluctant to raise concerns about cognitive function due to patient, carer, and family sensitivity, normalizing discussion around cognitive change as part of routine screening can facilitate ease among patients with chronic lung diseases.<sup>64</sup> Evaluation that includes performance-based tests (eg, Glittre-ADL test,<sup>65</sup> comprising trunk, arm and leg tasks), as well as evaluation of cognition in every day life (eg, Executive Function Performance Test)<sup>66</sup> may be one approach to evaluate how cognitive impairment interferes with essential daily activities (from showering to health management). This approach may be effective in directing cognitive-functional training that has meaningful impact on ADLs in people living with chronic lung diseases.

### Future Research Directions

Several research opportunities were identified to examine the interplay of cognition and physical function that may improve clinic care in people with chronic lung diseases. Top research priorities and key questions are summarized in Table 2 and e-Appendix 1. These focus on assessments, outcome measures, and standardization

of cognitive and physical function measures.

Stakeholders (ie, researchers, clinicians and patient partners) highlighted that consideration should be given to the clinical setting (ie, inpatient, outpatient) and required training regimens to optimize both cognitive and physical assessments.

The effects of cognitive impairment on respiratory exacerbations, ADLs, and self-management after exacerbations are not clear.<sup>7</sup> Thus, the meeting attendees questioned whether impairments observed during the stable state and after exacerbation may be attributed to cognitive impairment, poor motor control, or the cognitive interference from issues such as increased dyspnea. Future studies will need to consider the mechanistic underpinnings (ie, hypoxemia-related neuronal damage, systemic inflammation, physiological stressors), taking into account fluctuations with respiratory exacerbations.

Participants believed that dissemination of key evidence on cognitive-motor performance in people with chronic lung diseases should be undertaken through fact sheets and videos for clinicians and patients, as well as using presentations to various stakeholders at conference meetings. Strengthening existing collaborations and fostering new partnerships among patient partners, researchers, clinicians, and lung disease foundations will be important next steps to address the impact of motor control and daily function on these important patient-centered outcomes. In the end, providing rehabilitation through a cognitive lens has the potential to greatly improve daily function. The need for patients to have a better understanding of their condition and to play a major role is captured eloquently by one patient partner:

*"I think it is really important for ... clinicians to encourage patients to self-advocate ... I live with these chronic problems ... I'm not the disease!"*

### Discussion

This 2-day virtual meeting generated several ideas related to cognitive function and motor control in people with chronic lung diseases. The general consensus was that cognitive function and dyspnea were important contributors to motor control and daily function. PR, a multidisciplinary strategy, was identified as an excellent intervention that could improve respiratory and limb motor control. The evidence of the interplay of cognition and physical function is evolving, which led meeting participants to identify several future research initiatives.



**TABLE 2 ]** Key Research Questions for Assessment of Cognitive Function and Motor Control in Chronic Lung Diseases

Domain	Question
Assessments	<ul style="list-style-type: none"> <li>• Should cognitive screening (ie, use of Montreal Cognitive Assessment) be performed in studies evaluating physical performance or motor control?</li> <li>• What are the best clinical and research tools to evaluate cognitive and physical function in individuals with chronic lung disease?</li> <li>• What factors should be considered when evaluating cognitive function (ie, age, mood, education level, culture, socioeconomic status)?</li> <li>• What are the most relevant cognitive domains to evaluate in chronic lung disease?</li> <li>• What methodologic framework should be applied or developed to refine the variability of cognitive function measurements across research studies?</li> <li>• What mechanistic approaches could be used to evaluate cognition and motor control in chronic lung diseases?</li> <li>• How can we evaluate the contribution of lung disease severity compared with other comorbidities that predispose individuals to cognitive impairments?</li> <li>• Should cognitive screening and assessment of required physical function be integrated into evaluation of inhaler technique?</li> </ul>
Outcome measures	<ul style="list-style-type: none"> <li>• Can dual-task performance be integrated into clinical practice?</li> <li>• What is the association between dual-task decrements and outcomes such as falls, balance, daily activities, and health care utilization?</li> </ul>
Standard interventions/ approaches	<ul style="list-style-type: none"> <li>• What cognitive domains can be improved with exercise training?</li> <li>• What are the effective training protocols for specific cognitive domains?</li> <li>• Can a threshold of cognitive impairment predict pulmonary rehabilitation engagement or completion?</li> <li>• Can the use of adaptive platform trials be helpful in comparing various cognitive and exercise training interventions?</li> <li>• What is the optimal comparator group for assessment of cognition or physical function in people with chronic lung diseases?</li> <li>• What is the most effective way to educate health care providers regarding cognitive screening and, if needed, more extensive evaluation?</li> </ul>

Performance of routine daily activities often requires dual-tasking or multi-tasking (eg, talking or avoiding obstacles while walking). When cognitive capacity is limited or the cognitive load is increased from factors such as dyspnea, fatigue, or pain, decrements in one or both tasks can occur.<sup>21</sup> One example that can be applied in the clinical setting is the dual-task gait speed assessment (eg, walking and talking).<sup>12</sup> This stresses the cognitive and physical domains that parallel daily function and may be a more sensitive marker than separate cognitive or physical measures. A better understanding of the interplay between cognitive and physical function may provide additional prognostic utility in chronic lung diseases with the ability to identify patients at higher risk of falls or with significant limitations in ADLs and HRQOL, as shown in healthy older community-dwelling adults.<sup>67</sup> The integration of cognitive and physical function may also facilitate resource planning, clinical management decisions, and rehabilitation strategies.

Although the 2-day meeting on cognitive and physical function focused on people with COPD and ILD, many of these principles may be relevant to other respiratory

disease conditions. Impairments in physical domains of HRQOL, skeletal muscle function, and exercise capacity in conditions such as bronchiectasis,<sup>68</sup> pulmonary hypertension,<sup>69</sup> and asthma<sup>70</sup> are well described. Even though these conditions often affect younger individuals, evidence suggests that factors such as dyspnea, fatigue, hypoxemia, cerebrovascular abnormalities, and disease severity may contribute to cognitive limitations.<sup>71,72</sup> Thus, the risk of cognitive impairment is certainly applicable across several chronic lung diseases, but the optimal assessment method for evaluating cognition remains unclear due to differences in psychometric properties and the heterogeneity in the cognitive function of those with chronic lung diseases. Similarly, a focus on physical assessment instruments was beyond the scope of the current meeting, with several reports previously summarizing physical assessment measures.<sup>73,74</sup>

Investigations that evaluate cognitive processing related to PR are evolving, but the evaluation of physical function through a cognitive-motor control lens has not commonly been undertaken.<sup>21</sup> In a systematic review of 293 patients with COPD, exercise training (aerobic and

strength training exercises), as well as psychosocial and educational interventions, showed significant improvement in at least one cognitive domain (ie, speed, attention, verbal learning, memory).<sup>53</sup> The mechanistic underpinning for these cognitive changes remains to be determined, but factors such as physiological (ie, cerebral blood flow), psychosocial (ie, mood, energy), and cognitive-motor control are hypothesized to be important contributors. Furthermore, some types of training such as balance and IMT may have a greater influence on cognitive-motor control through neural plasticity compared with more commonly measured peripheral benefits such as strength, endurance, and exercise capacity.<sup>21,57</sup> Thus, future studies evaluating cognition with exercise training should consider their carryover effects to cognitive-motor skills (ie, executive function, learning and processing speed) required to perform daily tasks.

Cognitive measures have not been specifically included in the core outcome data set for PR for people with COPD. To our knowledge, these constructs were not formally evaluated in the Delphi process.<sup>75</sup> However, related core outcomes known to be affected by cognitive domains were included: dyspnea, fatigue, exercise capacity, HRQOL, ADLs, and health behaviors.<sup>14,21</sup> It is important to recognize that the core outcome set includes a minimum number of measurements to consider.<sup>75</sup> Furthermore, the American Thoracic Society workshop report on rehabilitation for people with respiratory disease and frailty highlights the importance of evaluating multidimensional measures of frailty, such as cognition and psychosocial factors, in addition to physical measures.<sup>74</sup> These multidimensional assessments may be beneficial in identifying individual needs and helping to tailor rehabilitation programs. Given the variability in cognitive assessments to date, a specific cognitive domain or threshold level has not been identified to indicate the patient's ability to engage or complete PR. Comprehensive assessments and multidisciplinary support (ie, geriatrics, social work, occupational therapy) may help improve patient engagement, daily function, and clinical outcomes as our understanding of cognition in PR advances.

## Summary

Cognitive and physical function are well described in chronic lung diseases, but our understanding of how they influence physical performance and ADLs is evolving. This 2-day virtual meeting brought together

patient partners, researchers, clinicians, and stakeholders to discuss related research priorities. The discussion focused on patient needs, dyspnea, cognition and its assessment, motor control, and physical limitations affecting multi-tasking and clinical outcomes such as falls and performance of daily activities. A better understanding of cognitive-motor mechanistic interactions may help disentangle their impacts on disability and provide a platform for more tailored rehabilitation strategies. The meeting generated several key research questions to advance the evidence in the areas of cognitive-motor interactions in chronic lung diseases and helped establish collaborations across several stakeholder groups.

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