Chapter 8
Technology to Enhance Engagement in Physical Activity

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Importance of Physical Activity and Exercise for Patients with Chronic Lung Disease

Aerobic exercise is important to combat the deconditioning that occurs in patients with chronic lung disease who characteristically experience breathlessness, which leads to a downward spiral of sedentary behavior, physical inactivity, muscle deconditioning, and functional disability [1–4]. Even the smallest incremental increase in exercise can lead to improvements in symptoms. Besides improving or maintaining exercise capacity and minimizing deconditioning, aerobic exercise has additional benefits of improving mood, health-related quality of life (HRQoL), and preventing or managing comorbidities [5]. For specific chronic pulmonary problems, regular exercise can reduce symptoms of dyspnea and pain in COPD [6], help manage

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M. L. Moy et al. (eds.), *Enhancing Patient Engagement in Pulmonary Healthcare*,
Respiratory Medicine, https://doi.org/10.1007/978-3-030-44889-9_8

secretions in patients with cystic fibrosis [7], and aid weight management in patients with asthma [8]. However, due to limited research, the role of exercise in the long-term management of interstitial lung disease and pulmonary hypertension is less clear [9, 10]. Traditionally, pulmonary rehabilitation (PR) has been the standard of care to deliver aerobic exercise in a supervised setting. By reducing overall muscle deconditioning, PR programs minimize symptoms and optimize exercise capacity despite chronic obstructive or restrictive ventilatory deficits [11].

More recently, the focus has shifted from aerobic exercise and has also included lifestyle physical activity (PA), such as walking, and interventions to promote PA that can be brought directly to the patient. Several factors have aided this shift, including the emergence of activity monitors to directly measure parameters such as daily step counts in the home setting [12–14], recognition of the major problem of access to conventional center-based PR programs [15], emergence of mind–body exercise programs [16], and data supporting that every step counts [17–24]. In this chapter, we review the role of technology to promote PA in normal healthy individuals, and then assess its role in addressing access and adherence to PA promotion—to bring PA programs directly to the patients and enhance long-term engagement in PA—in patients with chronic lung disease. Because the most work has been published in the use of technology-based PA interventions in persons with COPD, we focus on COPD and refer to other chronic pulmonary diseases when data are available. Lessons learned in the healthy population and patients with COPD can be applied to other chronic pulmonary diseases.

Persons with COPD with Higher Levels of Physical Activity Have Better Outcomes

Engagement in PA, assessed by questionnaire or directly measured with accelerometry, is a modifiable health behavior that affects COPD-specific outcomes, independent of lung function [17–24]. Even at the early stages of disease, persons with COPD spend significantly greater amounts of time being sedentary, and thus reduced time in PA, compared to healthy subjects [25–27]. COPD is also associated with aging-related comorbidities such as cardiovascular disease, diabetes mellitus, and osteoporosis—all of which may further contribute to functional limitations [28, 29].

Persons with COPD with a higher daily step count have a significantly lower risk of dying, independent of forced expiratory volume in one second (FEV_1) [18–20, 30]. Persons who walk the least at study entry have risks that are 2 and 6 times higher for exacerbations and COPD-related hospitalizations, respectively, compared to those who walked the most over a median follow-up of 16 months [21]. Patient self-report of any moderate to vigorous PA predicted a lower risk of 30-day hospital readmission after an index COPD hospitalization, compared to those who reported no moderate to vigorous PA [22]. These studies of daily step count, of any amount and intensity, support that every step walked can positively impact the disease course [18–24]. Based on these compelling observational studies, the Global Initiative for Chronic Obstructive Lung Disease (GOLD) guidelines recommend regular PA for all persons with stable COPD as standard of care [1].

Limitations of Conventional PR and Need for Technology-Based Interventions to Address Access and Adherence

The current standard of care to promote PA can be broadly separated into (1) PA counseling and (2) referral to conventional, supervised PR (PR) [11, 31]. Brief, episodic general advice to increase PA from a healthcare professional has limited success [31]. Conventional, supervised PR programs clearly reduce breathlessness and improve HRQoL and exercise capacity [11]. Although PR is an integral part of the clinical management of patients with COPD, PR programs face three significant problems: (1) in many regions, most patients who would benefit from PR cannot access it; (2) most patients who are offered to engage in PR prefer not to commit to a program that runs two to three times per week and requires a significant time commitment; and (3) there is no effective strategy to maintain engagement in PA and benefits after patients complete a PR program [32, 33]. Programs are available to only a small fraction of patients with COPD. As outlined by the European Respiratory Society's COPD audit, 50% of European respiratory units have access to PR and only 30% of eligible patients receive PR [34]. The American Association of Cardiovascular and Pulmonary Rehabilitation website lists 561 certified PR programs in the United States for the estimated 16 million Americans diagnosed with COPD [11]. Less than 13% of the potential candidates who would benefit from PR are referred by their healthcare professionals [33, 35]. An analysis of over 33,000 Medicare beneficiaries with COPD from January 1, 2003, to December 31, 2012, showed that only 1,239 persons (3.7%) used PR in 2012, with a dismal increase in utilization of 1.1% over the 10 years [36]. There is geographic disparity in availability since most programs are located at tertiary care centers and require patients to travel to the program 2–3 times a week [35, 37, 38]. This is a significant issue as highlighted in the National Emphysema Treatment Trial, which demonstrated that participants who lived >36 miles from the treatment facility were less likely to complete PR [39, 40].

For those who do complete conventional PR, there is no standardized intervention to maintain PA and thereby the benefits of PR [11, 32, 41–43]. PR programs, typically 9–12 weeks in duration, focus on short-term aerobic fitness and exercise capacity; they do not consistently result in sustained increases in PA assessed by community-based walking [44]. Only 41% of persons described themselves as regular walkers in the year after completion of PR [45]. In the absence of a maintenance strategy to motivate behavior change, gains in exercise capacity and HRQoL diminish toward pre-intervention levels as early as 3–6 months after program completion [11, 46]. These data support that novel interventions are needed to (1) bring exercise programs directly to the patient to improve access to PA promotion interventions and (2) promote engagement in PA and exercise anytime anywhere to maintain adherence to this behavior change over the long term.

Social Cognitive Theory Can Guide Technology-Based Strategies to Enhance Engagement in Physical Activity

A plethora of behavior change interventions have been designed to improve PA not only in healthy adults but also in patients with complex chronic conditions [47]. Many of these interventions have been delivered in face-to-face settings, which can be expensive and inhibit large-scale implementation [48, 49]. Therefore, easily deliverable, efficacious, and cost-effective interventions are needed to improve PA [49]. Technology-based platforms (e.g., internet, mobile devices, smartphone apps, pedometers) are increasingly being recognized as a potentially promising approach to increase PA [50]. These technologies can also be implemented in combination with face-to-face contacts or tele-coaching applications providing a mix of personalized contact and technology support.

Developing and testing best practices to leverage technology to promote PA in pulmonary populations begins with the understanding of relevant theoretical models of behavior change. One frequently adopted model is the social cognitive theory (SCT [51–54], also described in Chap. 6). SCT includes both strategies and constructs on how to educate, empower, guide, and motivate people to adapt health-promoting habits and reduce unhealthy habits [53]. SCT considers both how individuals learn and maintain behavior, and the social environment in which the behavior is performed. Many theories that are used in PA promotion research focus on initiating behavior, with limited consideration to maintaining that behavior [53, 55]. SCT is distinct in that it aims to explain how one regulates behavior to achieve and maintain goal-directed behavior [53].

The key constructs of SCT include (1) self-efficacy, (2) knowledge, (3) outcome expectations, (4) goals, and (5) facilitators and barriers [52, 53]. Self-efficacy is the central construct in SCT because it directly influences behavior, through one's beliefs in his/her ability to apply skills effectively in different situations, and can influence one's goals, outcome expectations, and barriers and facilitators [53, 55]. Knowledge of the health risks and benefits of different behaviors (e.g., risks and benefits of physical inactivity) can impact whether one engages in that behavior. Knowledge of health risks and benefits may encourage possible behavior change; however, these are not sufficient to initiate behavior change [53]. Self-efficacy refers to one's confidence to perform healthy behaviors (e.g., confidence to walk 30 minutes a day). Outcome expectations refer to one's anticipated costs and benefits of different health habits (e.g., expecting to fall or become short of breath during PA). Goals (e.g., walking 3,000 steps a day) and concrete plans for how to achieve those goals (such as joining a walking group that meets weekly) are critical for behavior change. Finally, perceived barriers (e.g., not having the environmental resources to safely walk) and facilitators (e.g., a friend to walk with) can strongly influence behavior change and maintenance [53]. SCT posits that these constructs all interact with one another, known as *reciprocal determinism* [53]. Self-efficacy influences outcome expectations and barriers/facilitators, and all five constructs influence goals. Similarly, all constructs influence behavior and motivation.

Understanding an individual's level of self-efficacy and knowledge, unique outcome expectations, goals, and perceived facilitators and barriers is critical for promoting engagement in PA. Through this understanding, interventions can be tailored to the individual in a stepwise manner [53]. For example, self-efficacy is one of the most consistently identified determinants of PA behavior [56]. If someone has a high sense of self-efficacy and positive outcome expectations for behavior change, they are likely to engage in PA with minimal guidance or support. On the other hand, individuals who are not confident in their ability to engage in PA and expect adverse consequences to engaging in PA will need more supportive interventions that are personalized to their specific barriers [57].

Albert Bandura, the pioneer of modern-day SCT, emphasizes three critical strategies to support the five constructs of SCT—providing social support, goal-setting and feedback, and barrier reduction [53]. Here, we describe how technology can be leveraged to deliver social support, goal-setting and feedback, and barrier reduction strategies, which may be helpful in overcoming common barriers to regular PA in both general and pulmonary populations. Technology also offers the ability to provide patients with continued support for behavior change in between healthcare professional visits. McEwan and colleagues [58] found promising evidence in a systematic review that PA interventions were effective regardless of whether the intervention was delivered in-person, via technology, or using a mixture of the two, suggesting that technology-based interventions, unlike many face-to-face studies, have the added benefit of being accessible anytime, anywhere and improving the reach of these interventions beyond that which can be done in person [58, 59]. We begin by examining literature from general, relatively healthy adults.

Strategy 1: Social Support

Social support, including encouragement and/or competition (e.g., trying to get more steps per day) from friends or family members, can increase engagement and adherence in PA interventions [60–64]. A recent meta-analysis concluded that higher social support specific to PA is associated with greater engagement in PA. SCT suggests that social support is beneficial only if it bolsters self-efficacy [54]. However, social support that fosters social *dependence* can undermine one's ability to cope and can be detrimental to behavior change success [53, 65]. Receiving support from others may pose a threat to one's sense of autonomy and self-efficacy [65]. Thus, it is best to provide social support and guidance that is conducive to self-efficacy enhancement for personal success [66]. For example, before deciding to offer social support, providers of social support should assess recipients' current level of self-efficacy and ask if they would like to be helped. Additionally, providers of social support should be trained to recognize and support recipients' autonomy [65] (e.g., listen to patients, explain how they have taken personal circumstances, concerns, and preferences into account in their recommendations, enable patients to query and if necessary correct their understandings about them, and ensure that patients feel they could choose against the recommendation without jeopardizing their ongoing care) [67].

Social support will be effective only if the user has members within his/her social circle with whom he/she can connect. Many older adults or adults with chronic disease face problems of social isolation, due in part to limited mobility or geographic isolation [68, 69]. As such, interventions that can leverage technology to help connect users to others would be helpful to facilitate social connections and encourage lasting changes in behavior. When using technology in patients, it is advised to verify whether these social networks are secure; for example, ensuring compliance with general data protection regulations in Europe.

Strategy 2: Goal-Setting and Feedback

Goal-setting has been a prominent intervention strategy to increase motivation and effect behavior change. Technology can be used to set automated gradual and realistic exercise goals in interventions that are personalized to the participant. A previous meta-analysis that examined interventions that compared goal-setting to no goal-setting found evidence for a significant increase in PA [58]. The attainment of goals can be enhanced by incorporating feedback, appropriate strategies to help attain said goals, and rewards or incentives [70]. Effective interventions should encourage setting realistic goals; the popular goal to walk 10,000 steps a day is not feasible for everyone, nor is it an evidence-based goal [71]. Gradual, small goals are more effective for long-term engagement compared to larger goals. When people are successful in meeting smaller goals, they can build momentum and over time will be more likely to reach larger goals.

Feedback of goal-achievement is another critical component for maintaining engagement in PA. Feedback can be as simple as letting the patient see their steps in real time (e.g., using a pedometer that displays step counts), or as sophisticated as providing dedicated visual and tailored feedback indicating if one achieved their goal or not (e.g., a website that uses an algorithm to tailor PA goals based on previous activity). Technology can provide feedback as a convenient means for informing, enabling, motivating, and guiding people in their quest to make lifestyle changes. Personalized feedback can be adjusted to participants' efficacy level, unique barriers to their lives, and the progress that they are making. Technology can be leveraged to provide personalized feedback that occurs more frequently than would feedback from a healthcare professional at episodic clinical visits. This personalized feedback may be especially effective in encouraging individuals to monitor their own activity and make behavioral changes [60, 72–74]. The ability to view successful behavior change by tracking one's own activity levels and exercise behaviors can motivate steady progress toward goals, while increasing self-efficacy.

Strategy 3: Barrier Reduction

There are many barriers to engaging in PA, including a lack of time, cost, pain or other symptoms, environmental (e.g., climate or geographical), or lack of enjoyment/willpower [75]. Perceiving certain barriers as insurmountable can foster helplessness; interventions should focus on trying to minimize the patient- and disease-specific barriers to PA. Interventions that specifically try to reduce the perception of these barriers (e.g., perceived lack of time [76]) can increase PA. Based on cognitive behavioral strategies, interventions that reframe or motivate one to overcome barriers (e.g., cognitive restructuring, emotional regulation), misconceptions, and negative expectancies can be successful promoting PA [77]. Technology-based interventions can help participants overcome access barriers such as the time required and/or transportation needed to travel to traditional, in-person PA intervention programs. Additionally, technology can provide easily personalized strategies to help overcome perceived barriers to PA (e.g., too tired, lack motivation, lack skills) [78].

Applying These Strategies in Pulmonary Populations

The use of technology is proving valuable for supporting PA engagement in pulmonary patients. Many of the lessons learned from the large body of research on behavior change and technology-mediated PA interventions in generally healthy adults can be applied to patients living with pulmonary diseases. Along with many of the same psychosocial and behavioral barriers to PA that relatively healthy adults face, barriers to PA in patients with pulmonary diseases are compounded by disease-specific symptoms (i.e., dyspnea, fatigue). SCT can be similarly applied to create technology-based platforms that encourage PA and other self-management behaviors in pulmonary disease. As described above for generally healthy adults, SCT-driven, multicomponent interventions, which combine strategies that foster social support, goal-setting, feedback, and barrier reduction are likely to increase daily PA in pulmonary patients as well [79]. Below, we detail previously published technology-mediated interventions that have been used to promote PA in pulmonary populations and the relevant SCT components that were included in the intervention. Importantly, many of these interventions have utilized more than one of these strategies as a multicomponent intervention. Details as to which components were involved in which interventions are presented in Table 8.1.

Table 8.1 SCT strategies in technology-mediated PA interventions for pulmonary disease

Study	Technology	Population	Intervention component				
			Social support	Goals	Feedback	Barriers	Education
Arbillaga-Etxarri [120]	Website/Pedometer	COPD	✓	✓	✓	✓	✓
Barberan-Garcia [93]	Smartphone/Pedometer	COPD/CHF/Stroke		✓	✓		✓
Choi [122]	Videoconferencing	Lung transplant	✓	✓			
Demeyer [100]	Smartphone/Pedometer	COPD		✓	✓		
Donesky [116]	Videoconferencing	COPD/HF	✓	✓			
Liu [118]	Cellphone	COPD		✓			
Mendoza [123]	Pedometer	COPD			✓		
Moy [98]	Website/Pedometer	COPD		✓	✓	✓	
Martinez[95]/Moy[96, 97]	Website/Pedometer	COPD	✓	✓	✓	✓	✓
Nguyen [84]	PDA/Website	COPD	✓	✓	✓		✓
Nguyen [101]	Cellphone	COPD		✓	✓	✓	
Park [121]	Smartphone	Lung Cancer	✓	✓	✓	✓	✓
Tabak [87]	Website	COPD		✓	✓		
van der Weegen [88]	Smartphone/Pedometer/ Website	COPD	✓	✓	✓	✓	✓
Voncken-Brewster [119]	Website	COPD	✓	✓	✓	✓	
Vorrink [102]	Smartphone/Website	COPD		✓	✓		
Wan [89]	Website/Pedometer	COPD	✓	✓	✓	✓	✓

Strategy 1: Social Support

Patients with pulmonary disease face limitations related to chronic conditions, which may result in social disconnectedness or social isolation [80], making strategies that foster social support potentially even more important for effective PA interventions. In a recent cross-sectional study, social support was significantly related to change in patients' daily step counts [81, 82]. Research that randomly assigned patients with COPD to receive a telehealth self-management intervention found significant improvements in perceived social support and a significant decrease in dyspnea compared to those who did not receive the telehealth intervention [83]. In another trial, researchers utilized web-based education modules with weekly live chat sessions, which were designed to increase peer support in patients with COPD. While COPD patients' perceptions of *general* social support did not significantly increase, participants did report that they felt supported to either start or maintain their exercise programs and significantly increased their duration of endurance exercise per week [84].

Strategy 2: Goal-Setting and Feedback

Setting meaningful and achievable goals facilitates PA in pulmonary patients, as documented in a systematic review of PA interventions [85]. Meaningful goals should be important to the patients. These goals can be based on a patient's functional performance, energy levels, muscle mass, strength, body weight, psychosocial well-being, and resistance to illness, as well as symptoms [85]. Having meaningful goals (e.g., playing with grandchildren) has been identified as a motivator for PR attendance and PA engagement [85, 86]. Along with meaningful goals, goals should be realistic. If a patient with COPD has been walking an average of only 2,000 steps a day, asking them to instantly increase to 10,000 is unrealistic and demotivating. For example, patients with COPD who just completed 3 months of PR were randomly assigned to use a smartphone to track their PA against goals set by a physiotherapist [87]. Interestingly, there was no significant increase in PA [87]. It is possible that because patients had just completed PR and likely already significantly increased their PA, asking them to increase their PA even more was not an attainable goal. Setting such unrealistic goals that patients cannot achieve can be detrimental to their self-efficacy [53].

Providing feedback related to patients' PA goals is an effective intervention strategy in pulmonary patients. In another RCT, "It's LiFe!," a feedback tool was developed that integrated an activity tracker, smartphone, and website for patients with COPD and/or type-2 diabetes that measured activity behavior and automatically generated feedback to the patient and healthcare professional [88]. Patients using the tool engaged in significantly more minutes of exercise a day (approximately 12 minutes) [88]. Goal-setting and feedback are strongly tied to one's self-efficacy. Providing patients with feedback regarding their PA goals provides them with evidence that it is within their power to be more active. Through feedback, successes can build and strengthen self-efficacy, and positive outcome expectations can provide patients with incentives to continue to be active [55]. In a recent RCT, patients with COPD were randomly assigned to receive a web-based intervention that provided personalized goals based on recent activity levels in real time, with a graphical display of step counts to provide patients with feedback in relation to their step-count goal [89]. Compared to patients who were not given the intervention, participants significantly increased their levels of PA [89]. The use of technology provided patient with immediate and visual feedback.

Strategy 3: Barrier Reduction

Usual barriers to PA can be compounded by disease-specific barriers. A systematic review found the following barriers to PA for patients with COPD: coping with changing health status, particularly the limitations of breathlessness and related fear of breathlessness; lack of support and encouragement from others; practical difficulties of access to structured PA intervention programs; and perceived or actual difficulties with the requirements of the programs themselves [85]. In another cross-sectional study, worries about becoming short of breath, needing to use inhalers, and oxygen levels becoming low were the most commonly reported barriers to being active in a sample of patients with COPD [90]. These concerns about becoming short of breath and needing to use an inhaler were significantly related to less PA [90]. Barriers to PA may be related to disease complexity (managing a chronic disease or comorbidities) [85, 86], aging, prior negative experiences with PA or PR, limitations in oxygen therapy [86], or environmental challenges (weather, timing and location of PA interventions, transportation, finance) [85, 86]. A recent RCT of a web-based PA intervention in patients with COPD demonstrated significant maintenance of PA despite barriers due to seasonal variations [89]. Indeed, this intervention did provide content on ways to walk despite bad weather (e.g., on a treadmill or in a mall) [89]. Interventions that do not necessarily increase PA can still be efficacious if they can maintain PA, as delaying the natural or cyclical progression of declines in PA that can occur with chronic disease is critical for health outcomes.

Strategy 4: Disease Education

In addition to the behavior change techniques guided by SCT—social support, goal-setting and feedback, and barrier reduction—patients living with complex chronic pulmonary diseases would also benefit from disease education to help reduce the perception of potential barriers and encourage better self-management. Traditional in-person visits are episodic and do not offer continuous support and education; technology-mediated platforms can help to make disease education and barrier reduction more continuous and supportive. Advancements in healthcare have led to more people living with chronic conditions for longer amounts of time. Increased attention has been placed on developing effective approaches to manage chronic symptoms to maintain patient independence and HRQoL [91]. Approaches to managing chronic conditions are now emphasizing the crucial role that patients play in guiding their own health and disease trajectory [91]. Self-management strategies can be effective across a variety of different diseases, including controlling symptoms and disability, monitoring physical indicators of disease/disability, handling complex medication regimens, adjusting to difficult lifestyle adjustments, engaging in valuable interactions with healthcare professionals, maintaining a healthy diet, and engagement in PA [92]. Therefore, interventions that are developed to enhance self-management behaviors, such as PA, would benefit from incorporating disease and self-management education. Technology can be used to guide patients to take initiative in their healthcare. In a multisite trial, patients with COPD used a smartphone to access tailored and regularly updated disease and self-management information [93]. At one of the sites, patients in the technology-mediated intervention significantly increased and maintained at follow-up how far they walked in the 6-minute walk test (6MWT) by about 8% [93]. In another trial that utilized a website to deliver a dyspnea self-management intervention for patients with COPD, patients received web-based education modules, which resulted in significant improvements in knowledge of dyspnea management strategies [84]. Technology-based strategies, anywhere, any time, and in the comfort of their own home, can educate patients about their disease and proper self-management strategies. This can enable them to take initiative in their own healthcare, thus increasing their sense of self-efficacy and facilitating behavior change [53]. It is important to note the patient's perception of usability (e.g., web interface) is an important predictor of engagement [94]. Therefore, healthcare professionals and researchers alike should involve eHealth specialists to develop effective, usable interventions.

Multicomponent Interventions

Multicomponent interventions that use more than one strategy (e.g., social support, goals and feedback, barrier reduction, disease education) to try to improve participants' knowledge, self-efficacy, outcome expectations, goals, and perceived facilitators and reduced perceived barriers are more effective than interventions that use only one component to try to improve PA [53, 54, 57]. However, as multicomponent interventions can be burdensome and costly, technology can be leveraged to deliver many components at once. One study, Taking Healthy Steps (THS [95–97]), used a website intervention based on the Theory of Self-Regulation, which used goal-setting via a pedometer plus a website that provided individualized step-count goals, iterative step-count feedback, education on disease self-management and motivation, and an online community of social support. Patients with COPD, who used a pedometer paired with the theory-based website intervention, increased their PA by

Fig. 8.1 This screenshot shows an example of the home page for Every Step Counts, a web-based multicomponent physical activity intervention for COPD. Every Step Counts has shown significant promise for promoting physical activity using the following theoretically driven strategies: social support, goal-setting and feedback, barrier reduction, and disease education. These strategies can support patients' self-efficacy, knowledge, outcome expectations, goals, facilitators, and barriers

778 steps per day and improved HRQoL at 4 months [96]. Similar improvements were seen in another study using the same multicomponent theory-based intervention, Every Step Counts (ESC), which extended THS in an independent and well-characterized cohort with in-person assessments of physiological and psychosocial variables [89, 98]. In a pilot study with a single-arm design, patients who used ESC significantly increased their steps by an average of 1,263 steps per day [98]. In the larger RCT, patients who used ESC increased their average daily steps by approximately 804 steps per day [89]. Figure 8.1 depicts the home page for ESC, which includes multiple components to foster social support (online forum), goal-setting and iterative feedback, barrier reduction, and disease education. Previous research suggests that the minimal clinically important difference (MCID) for steps in COPD ranges from 350 steps/day to 1,100 steps/day [99], indicating that the increases demonstrated in previous multicomponent studies are not only statistically significant, but also clinically meaningful.

Another study utilized a smartphone app to deliver feedback on steps, individualized step goals, text messages, and occasional telephone contact with the research team on an as-needed basis [100]. This semiautomated, pedometer-mediated telecoaching intervention and smartphone app demonstrated significant increases (1,469 steps per day, on average) in PA in patients with COPD [100]. Interestingly, when comparing delivery methods (technology compared to face-to-face), there does not appear to be significant differences in exercise behaviors in those who received a cellphone texting intervention [101] or an internet-based intervention [84] compared to face-to-face interventions, though these interventions were designed to improve dyspnea, with exercise behaviors as a secondary outcome. While effectiveness may not significantly differ, technology-mediated interventions are becoming more pervasive due to their promise of increased accessibility, ease of personalization, and cost-effectiveness.

Important Considerations

Sociodemographic Differences

When developing technology-mediated interventions to promote PA, it is important to consider the target population (e.g., age, health) and the feasibility of using specific technology (e.g., pedometer, website, and app). It is important to design the technology with the user in mind or even together with users in an iterative process (e.g., Vorrink [102]). Previous studies have documented sociodemographic factors associated with mobile health and app use, suggesting that those who are younger, more educated, report excellent health, and have higher income are more likely to use health apps [103–106]. Unfortunately, this population is not the population who could potentially benefit the most from using health technology. Therefore, it is important to consider these sociodemographic differences when identifying appropriate technology-based platforms for PA interventions in chronic pulmonary disease.

Digital Literacy

While technology offers a possible solution to the geographic disparities accessing many face-to-face interventions, there is a risk that they could increase health inequalities due to a "digital divide" in both access to the internet and confidence and skills to use the technology (i.e., digital literacy) [107]. It is also critical that users can easily and consistently sync, view, and understand the information provided by the technology [108]. It helps to involve users in the design of the technology, as they are the ones who will be using it.

Accuracy

Another important consideration is the accuracy of the technology. Pedometers may underestimate activity at a slow speed, as is typical in patients with chronic lung disease. Therefore, accuracy can vary between patients with chronic lung disease and healthy adults [17]. Additionally, significant variation in the accuracy of an accelerometer can be observed based on walking speed [109].

Privacy

Technology can deliver accessible, potentially cost-effective services to promote PA to those who need them most. However, patient engagement with these interventions may face many barriers if the intervention cannot ensure privacy of confidential data, reliable and consistent technology services, usability, and many others [110]. Many technology-based health services rely on cloud computing for data storage. However, some argue that the use of cloud storage poses increased security threats for data transmission and storage [110]. Such privacy concerns are likely to impact some patients' willingness to use technology-based services. Even if we can get patients to use these devices (e.g., Apple Watch or Fitbit), it is imperative that researchers are clear in how to access the patients' data securely. Stakeholders of technology-based services must consider this critical aspect of data storage when attempting to engage patients and implement these services [110].

Future Directions

As technology continues to advance, there is an increasing amount of forthcoming research developing, evaluating, and implementing technology-mediated interventions to promote PA in pulmonary patients. Examining long-term maintenance, Koreny et al. [111] have recently described certain patient characteristics (e.g., engaging in greater levels of PA at baseline, living with a partner, and in a less disadvantaged neighborhood) that predicted adherence to a 12-month intervention. Other avenues being pursued are examining ways to not only increase PA time but reduce sedentary time as well. A recently published trial found a disease-education and self-monitoring intervention using wearable technology feasible and acceptable to reduce sedentary behavior for individuals with COPD admitted to the hospital for an acute exacerbation [112]. Virtual care, or telehealth, is another avenue of technology currently being examined to promote PA in pulmonary patients. In a feasibility study, researchers assessed a tablet-based PA intervention in virtual groups for patients with COPD, with promising findings for increasing PA [113]. Similarly, a recently published protocol aims to compare the efficacy of home-based telerehabilitation to traditional center-based PR in people with chronic respiratory disease [114]. These studies represent just some of the interesting and promising lines of work to look forward to.

Technology to Deliver a Wide Array of Physical Activity Modalities

Walking has gained considerable interest in recent years as a feasible and preferred strategy for increasing PA in many patients. Walking is a free, low-impact activity that can be done practically anywhere and at any time [71]. As such, many technologies are geared specifically toward increasing steps. However, there are other low-impact, accessible activities, such as yoga or Tai Chi (see Chap. 9), that can serve as alternative forms of exercise for health promotion. Compared to PA interventions, these types of activities are structured, timed, and use specific exercises at low intensity. Yoga and Tai Chi are both low-impact activities that emphasize coordination between movement and breath. These activities offer a logical, complementary therapy for pulmonary patients [115–117]. Technology-delivered yoga interventions have been previously assessed in pulmonary patients, though this line of research is limited. A recent study examined the feasibility and clinical outcomes of a home-based yoga program that used videoconferencing (i.e., TeleYoga) to connect patients with COPD and heart failure to live yoga classes [116]. Patients did not demonstrate significant improvement in muscle strength, or the 6MWT distance; however, following performance of the 6MWT, shortness of breath and distress related to dyspnea significantly improved after the intervention [116]. The findings suggest that, despite disease-specific frailty, TeleYoga was a feasible and acceptable method to encourage participation in yoga for cardiopulmonary patients. The benefits of Tai Chi for health are well established; however, to our knowledge, technology-based Tai Chi interventions for pulmonary patients have not yet been developed. Given the benefits of other variations of PA, future work should continue to develop and test theoretically driven, technology-based platforms to promote other types of PA as well. Compared to daily physical activities such as walking, Tai Chi and yoga are unique in that they are typically delivered in a class setting. Videos could be uploaded to a website (e.g., YouTube) to make these classes more easily accessible.

Long-Term Maintenance

Perhaps one of the greatest challenges to encouraging engagement in PA is the long-term maintenance of said engagement. Generally, many technology-based PA intervention studies fail to report follow-up data; as such, little is known about the duration or predictors of maintained engagement in activity. In pulmonary patients, the longest follow-up period appears to be 12 months. There is mixed evidence for long-term maintenance of PA and results are still rather disappointing. Moy and colleagues [97] report on the long-term effects of THS, the website and pedometer-based intervention in patients with COPD at 8 months after a successful 4-month intervention. Although the website was efficacious for increasing daily step counts at the end of the 4-month intervention [96], this increase was not maintained during the subsequent 8-month follow-up [97]. Liu et al. [118] found that patients with COPD increased their walking by about 505 steps following a home-based program at 12 weeks, though these improvements did not persist at 9 months. Similarly, Vorrink et al. [102] did not find significant changes in PA during a 12-month pedometer-based intervention. In their long-term follow-up, Moy et al. [97] also did not find evidence of maintained daily steps in patients with COPD who received a web-based intervention. In another technology-mediated, multicomponent study, researchers did not see any significant changes in PA in patients with COPD [119]. The authors note that only 36% of the intervention group used the technology, citing this as a possible explanation for the nonsignificant effect on PA [119]. Here, the participants were given an option to choose which intervention components they used, though they could have benefitted from more guided and supported use of the intervention components (e.g., instructed where to go and what to look at) [119].

Some studies have documented hope for long-term maintenance of PA. Arbillaga-Etxarri et al. found that patients with COPD who completed a 12-month multicomponent intervention increased their steps by an average of 957 steps compared to baseline. This study utilized an urban training program, which provided participants with feedback, motivation, information, and support via a pedometer, calendar, PA brochure, website, phone text messages, walking groups, and a phone number [120]. Of note, the study was rolled out in Barcelona (Spain) where climate permits walking outside on most days of the year. However, when they examined effectiveness of the intervention by examining all enrolled participants (i.e., intention-to-treat analysis), there were no significant differences in steps between the intervention and control groups. This suggests that this multicomponent, technology-mediated intervention was only successful in improving PA in adherent patients [120]. Perhaps revising the statistical approach, moving away from "average effects" to "responder analysis" and identifying a larger fraction of responders in cohorts of patients using step counters and feedback to maintain PA might shed a different light on findings so far. Since the intervention is relatively cheap for healthcare systems to implement, they can be worthwhile even if they help only a small minority of patients (much like smoking cessation).

As much as it is unlikely to achieve benefits of these interventions in all patients, it is likely that these interventions will lose appeal over time. However, in those patients where the intervention remains a pleasant support and when no exacerbations are encountered, it might be that the intervention is helpful in a fraction of patients. In one study, patients were less likely to be adherent if they had a lower FEV_1/FVC ratio, diabetes, currently smoke, or indicated a greater score on a depression measure [120]. Future research that can identify individual factors that predict long-term response to PA interventions will be helpful to effectively personalize PA interventions.

Long-term maintenance of PA is difficult to achieve in all populations and can be especially difficult in patients with chronic, complex diseases like COPD who face exacerbations and/or comorbidities. It is necessary that PA interventions for pulmonary patients involve healthcare professionals; the use of technology can be instrumental to help clinical teams monitor and motivate patients' PA. Technology is a helpful tool to assist promoting long-lasting changes in PA by allowing healthcare professionals to view cumulative PA data and patterns of increase and decrease, which can be correlated with clinical status. For example, knowing a patient's baseline level of PA can offer concrete guidance to a healthcare professional who is counseling a patient recovering from a COPD exacerbation to increase PA and has a goal to return to a specific known baseline. Activity trackers, apps, and web-based platforms have the capability to integrate multiple theory-based strategies such as social support, goal-setting, and feedback geared to the specific problems of individuals with COPD, barrier reduction, and disease education.

Assessing Technology-Mediated Interventions in Other Pulmonary Populations

The majority of technology-mediated exercise interventions available for pulmonary patients have been confirmed efficacious where COPD is present. Currently, there is a limited amount of work that has explored the efficacy of technology-mediated PA interventions in other pulmonary patient populations. For example, in a recent study, researchers report that a smartphone app–based PR program was effective and feasible to improve exercise capacity (as measured by the 6MWT; patients were able to walk 68 more meters after 12 weeks) in patients with advanced lung cancer undergoing chemotherapy [121]. In another study, researchers piloted a telerehabilitation platform for lung transplant recipients. This intervention included individualized aerobic and strength training plans, video conferencing, and real-time demonstrations of exercises with healthcare professionals [122]. Patients in the intervention demonstrated improved exercise capacity, strength, and steps from pre- to post-intervention. It is important to note that PA programs are not exact substitutes for PR programs. PR programs typically involve more strenuous strength training and target exercise capacity, as opposed to daily PA. Future research would benefit from exploring technology-based interventions to increase PA in other pulmonary populations.

Conclusion

In conclusion, patients with chronic pulmonary disease will benefit from engaging in PA. PA is a significant predictor of health outcomes, comorbidities, and mortality, but engagement in PA can be especially challenging for patients living with a chronic pulmonary disease. Therefore, it is critical to understand best practices to encourage engagement and maintenance of PA. One of the pressing remaining questions is how to effectively encourage these patients to engage in and adhere to PA. Researchers, healthcare professionals, interventionists, and all others seeking to encourage PA promotion should incorporate theory- and evidence-based decisions that will foster patients' knowledge, self-efficacy, outcome expectations, goals, and perceived facilitators, and reduce perceived barriers to PA. When developing and recommending interventions, multiple components should be leveraged to increase patients' adherence to the intervention, and ultimately their chance for success. For example, a clinical team could present a suite of possible options to support behavior change in patients and allow patients a choice or the possibility to choose another approach if a first approach is not leading to the anticipated outcome. This is common practice in other behavior change interventions such as smoking cessation or weight loss interventions.

Technology offers a unique method to deliver multicomponent, efficacious interventions to encourage PA, but it is acknowledged that technological solutions are not one size fits all. Understanding how to utilize technology to effectively encourage PA is critical. Similarly, it is necessary to understand who will benefit the most from which intervention. Sociodemographic (e.g., age, education, income, health status) and other individual differences (e.g., self-efficacy) can significantly impact the efficacy of an intervention and should be carefully considered. Other caveats to consider when leveraging technology to promote activity are the potential threats to data privacy and security, as well as threats to accuracy and reliability. The potential benefits of using technology to encourage PA in pulmonary patients outweigh many of the addressable cons. Future research and intervention development will benefit from assembling teams of consultants who are well equipped to address these important considerations, such as eHealth experts.

References

1. Vogelmeier CF, Criner GJ, Martinez FJ, et al. Global strategy for the diagnosis, management, and prevention of chronic obstructive lung disease 2017 report. GOLD Executive Summary. Am J Respir Crit Care Med. 2017;195(5):557–82.
2. Sutherland ER, Cherniack RM. Management of chronic obstructive pulmonary disease. N Engl J Med. 2004;350(26):2689–97.
3. Pleguezuelos E, Esquinas C, Moreno E, et al. Muscular dysfunction in COPD: systemic effect or deconditioning? Lung. 2016;194(2):249–57.
4. Gea J, Pascual S, Casadevall C, Orozco-Levi M, Barreiro E. Muscle dysfunction in chronic obstructive pulmonary disease: update on causes and biological findings. J Thorac Dis. 2015;7(10):E418–38.
5. Gordon CS, Waller JW, Cook RM, Cavalera SL, Lim WT, Osadnik CR. Effect of PR on symptoms of anxiety and depression in chronic obstructive pulmonary disease: a systematic review and meta-analysis. Chest. 2019;156(1):80–91.
6. Harrison SL, Lee AL, Elliott-Button HL, et al. The role of pain in PR: a qualitative study. Int J Chron Obstruct Pulmon Dis. 2017;12:3289–99.
7. Radtke T, Boni L, Bohnacker P, et al. Acute effects of combined exercise and oscillatory positive expiratory pressure therapy on sputum properties and lung diffusing capacity in cystic fibrosis: a randomized, controlled, crossover trial. BMC Pulm Med. 2018;18(1):99.
8. Okoniewski W, Lu KD, Forno E. Weight loss for children and adults with obesity and asthma. A systematic review of randomized controlled trials. Ann Am Thorac Soc. 2019;16(5):613–25.
9. Granger CL, Morris NR, Holland AE. Practical approach to establishing PR for people with non-COPD diagnoses. Respirology. 2019;24:879–88.
10. Nogueira-Ferreira R, Moreira-Goncalves D, Santos M, Trindade F, Ferreira R, Henriques-Coelho T. Mechanisms underlying the impact of exercise training in pulmonary arterial hypertension. Respir Med. 2018;134:70–8.
11. Spruit MA, Singh SJ, Garvey C, et al. An official American Thoracic Society/European Respiratory Society statement: key concepts and advances in PR. Am J Respir Crit Care Med. 2013;188(8):e13–64.
12. Danilack VA, Okunbor O, Richardson CR, Teylan M, Moy ML. Performance of a pedometer to measure physical activity in a U.S. cohort with chronic obstructive pulmonary disease. J Rehabil Res Dev. 2015;52(3):333–42.
13. Langer D, Gosselink R, Sena R, Burtin C, Decramer M, Troosters T. Validation of two activity monitors in patients with COPD. Thorax. 2009;64(7):641–2.
14. Rabinovich RA, Louvaris Z, Raste Y, et al. Validity of physical activity monitors during daily life in patients with COPD. Eur Respir J. 2013;42(5):1205–15.

15. Rochester CL, Vogiatzis I, Holland AE, et al. An official American Thoracic Society/European Respiratory Society policy statement: enhancing implementation, use, and delivery of PR. Am J Respir Crit Care Med. 2015;192(11):1373–86.
16. Gendron LM, Nyberg A, Saey D, Maltais F, Lacasse Y. Active mind-body movement therapies as an adjunct to or in comparison with PR for people with chronic obstructive pulmonary disease. Cochrane Database Syst Rev. 2018;10(10):CD012290.
17. Watz H, Pitta F, Rochester CL, et al. An official European Respiratory Society statement on physical activity in COPD. Eur Respir J. 2014;44(6):1521–37.
18. Waschki B, Kirsten A, Holz O, et al. Physical activity is the strongest predictor of all-cause mortality in patients with COPD: a prospective cohort study. Chest. 2011;140(2):331–42.
19. Vaes AW, Garcia-Aymerich J, Marott JL, et al. Changes in physical activity and all-cause mortality in COPD. Eur Respir J. 2014;44(5):1199–209.
20. Moy ML, Gould MK, Liu IA, Lee JS, Nguyen HQ. Physical activity assessed in routine care predicts mortality after a COPD hospitalisation. ERJ Open Res. 2016;2(1).
21. Moy ML, Teylan M, Weston NA, Gagnon DR, Garshick E. Daily step count predicts acute exacerbations in a US cohort with COPD. PLoS One. 2013;8(4):e60400.
22. Nguyen HQ, Chu L, Amy Liu I-L, et al. Associations between physical activity and 30-day readmission risk in chronic obstructive pulmonary disease. Ann Am Thorac Soc. 2014;11(5):695–705.
23. Garcia-Aymerich J, Lange P, Benet M, Schnohr P, Anto JM. Regular physical activity reduces hospital admission and mortality in chronic obstructive pulmonary disease: a population based cohort study. Thorax. 2006;61(9):772–8.
24. Moy M, Teylan M, Weston N, Gagnon D, Danilack V, Garshick E. Daily step count is associated with plasma CRP and IL-6 in a US cohort with COPD. Chest. 2013;10.
25. Watz H, Waschki B, Meyer T, Magnussen H. Physical activity in patients with COPD. Eur Respir J. 2009;33(2):262–72.
26. Pitta F, Troosters T, Spruit MA, Probst VS, Decramer M, Gosselink R. Characteristics of physical activities in daily life in chronic obstructive pulmonary disease. Am J Respir Crit Care Med. 2005;171(9):972–7.
27. Van Remoortel H, Hornikx M, Demeyer H, et al. Daily physical activity in subjects with newly diagnosed COPD. Thorax. 2013;68(10):962–3.
28. McNamara RJ, McKeough ZJ, McKenzie DK, Alison JA. Physical comorbidities affect physical activity in chronic obstructive pulmonary disease: a prospective cohort study. Respirology. 2014;19(6):866–72.
29. Divo M, Cote C, de Torres JP, et al. Comorbidities and risk of mortality in patients with chronic obstructive pulmonary disease. Am J Respir Crit Care Med. 2012;186(2):155–61.
30. Vaes AW, Garcia-Aymerich J, Marott JL, et al. Changes in physical activity and all-cause mortality in COPD. Eur Respir J. 2014:erj00232–02014.
31. Williams NH. Promoting physical activity in primary care. Br Med J. 2011;343.
32. Jenkins AR, Gowler H, Curtis F, Holden NS, Bridle C, Jones AW. Efficacy of supervised maintenance exercise following PR on healthcare use: a systematic review and meta-analysis. Int J Chron Obstruct Pulmon Dis. 2018;13:257–73.
33. Johnston K, Grimmer-Somers K. PR: overwhelming evidence but lost in translation? Physiother Can. 2010;62(4):368–73.
34. Roberts M, Hartl S, Lopes-Campos J. An international comparison of COPD Care in Europe: results of the first European COPD audits. Lausanne: European Respiratory Society; 2012.
35. Johnston KN, Young M, Grimmer KA, Antic R, Frith PA. Barriers to, and facilitators for, referral to PR in COPD patients from the perspective of Australian general practitioners: a qualitative study. Prim Care Respir J. 2013;22:319.
36. Nishi SP, Zhang W, Kuo Y-F, Sharma G. PR use in older adults with chronic obstructive pulmonary disease, 2003-2012. J Cardiopulm Rehabil Prev. 2016;36(5):375.
37. Fischer MJ, Scharloo M, Abbink JJ, et al. Drop-out and attendance in PR: the role of clinical and psychosocial variables. Respir Med. 2009;103(10):1564–71.

38. Keating A, Lee A, Holland AE. What prevents people with chronic obstructive pulmonary disease from attending PR? A systematic review. Chron Respir Dis. 2011;8(2):89–99.
39. Fan VS, Giardino ND, Blough DK, Kaplan RM, Ramsey SD, Group NR. Costs of PR and predictors of adherence in the National Emphysema Treatment Trial. COPD: J Chron Obstruct Pulmon Dis. 2008;5(2):105–16.
40. Fishman A, Martinez F, Naunheim K, et al. A randomized trial comparing lung-volume-reduction surgery with medical therapy for severe emphysema. N Engl J Med. 2003;348(21):2059–73.
41. Ringbaek T, Brondum E, Martinez G, Thogersen J, Lange P. Long-term effects of 1-year maintenance training on physical functioning and health status in patients with COPD: a randomized controlled study. J Cardiopulm Rehabil Prev. 2010;30(1):47–52.
42. Spencer LM, Alison JA, McKeough ZJ. Maintaining benefits following PR: a randomised controlled trial. Eur Respir J. 2010;35(3):571–7.
43. Steele BG, Belza B, Cain KC, et al. A randomized clinical trial of an activity and exercise adherence intervention in chronic pulmonary disease. Arch Phys Med Rehabil. 2008;89(3):404–12.
44. Cindy Ng LW, Mackney J, Jenkins S, Hill K. Does exercise training change physical activity in people with COPD? A systematic review and meta-analysis. Chron Respir Dis. 2012;9(1):17–26.
45. Heppner PS, Morgan C, Kaplan RM, Ries AL. Regular walking and long-term maintenance of outcomes after PR. J Cardpulm Rehabil. 2006;26(1):44–53.
46. Ries AL, Kaplan RM, Myers R, Prewitt LM. Maintenance after PR in chronic lung disease: a randomized trial. Am J Respir Crit Care Med. 2003;167(6):880–8.
47. Sweet SN, Fortier MS. Improving physical activity and dietary behaviours with single or multiple health behaviour interventions? A synthesis of meta-analyses and reviews. Int J Environ Res Public Health. 2010;7(4):1720–43.
48. Cavill N, Ells L. Treating adult obesity through lifestyle change interventions. A briefing paper for commissioners. In: Oxford: National Obesity Observatory; 2010.
49. Davies CA, Spence JC, Vandelanotte C, Caperchione CM, Mummery WK, Activity P. Meta-analysis of internet-delivered interventions to increase physical activity levels. Int J Behav Nutr Phys Act. 2012;9(1):52.
50. Heerden AV, Tomlinson M, Swartz LJ. Point of care in your pocket: a research agenda for the field of m-health. Bull World Health Organ. 2012;90:393–4.
51. Bandura A. Self-efficacy: toward a unifying theory of behavioral change. Psychol Rev. 1977;84(2):191–215.
52. Bandura A. The explanatory and predictive scope of self-efficacy theory. J Soc Clin Psychol. 1986;4(3):359–73.
53. Bandura A. Health promotion by social cognitive means. Health Educ Behav. 2004;31(2):143–64.
54. Bandura A. Social cognitive theory in cultural context. Appl Psychol. 2002;51(2):269–90.
55. Bandura A. Health promotion from the perspective of social cognitive theory. Psychol Health. 1998;13(4):623–49.
56. McAuley E, Blissmer B. Self-efficacy determinants and consequences of physical activity. Exerc Sport Sci Rev. 2000;28(2):85–8.
57. Robinson S, Lachman M. Perceived control and behavior change: a personalized approach. In: Perceived control: theory, research, and practice in the first 50 years; New York, NY: Oxford University Press. 2016; p. 201–27.
58. McEwan D, Harden SM, Zumbo BD, et al. The effectiveness of multi-component goal setting interventions for changing physical activity behaviour: a systematic review and meta-analysis. Health Psychol Rev. 2016;10(1):67–88.
59. Fanning J, Mullen SP, McAuley E. Increasing physical activity with mobile devices: a meta-analysis. J Med Internet Res. 2012;14(6):e161.
60. Ledger D, McCaffrey D. Inside wearables: how the science of human behavior change offers the secret to long-term engagement. Endeavor Partners. 2014;200(93):1.

61. Rovniak LS, Kong L, Hovell MF, et al. Engineering online and in-person social networks for physical activity: a randomized trial. Ann Behav Med. 2016;50(6):885–97.
62. Victor CR, Rogers A, Woodcock A, et al. What factors support older people to increase their physical activity levels? An exploratory analysis of the experiences of PACE-Lift trial participants. Arch Gerontol Geriatr. 2016;67:1–6.
63. Richardson CR, Mehari KS, McIntyre LG, et al. A randomized trial comparing structured and lifestyle goals in an internet-mediated walking program for people with type 2 diabetes. Int J Behav Nutr Phys Act. 2007;4:59.
64. Maher C, Ferguson M, Vandelanotte C, et al. A web-based, social networking physical activity intervention for insufficiently active adults delivered via Facebook app: randomized controlled trial. J Med Internet Res. 2015;17(7):e174.
65. Warner LM, Ziegelmann JP, Schüz B, Wurm S, Tesch-Römer C, Schwarzer R. Maintaining autonomy despite multimorbidity: self-efficacy and the two faces of social support. Eur J Ageing. 2011;8(1):3–12.
66. Bandura A. Psychological aspects of prognostic judgments. In: Prognosis of neurological disorders; New York, New York: Oxford University Press. 1992. p. 11–27.
67. Entwistle VA, Carter SM, Cribb A, McCaffery K. Supporting patient autonomy: the importance of clinician-patient relationships. J Gen Intern Med. 2010;25(7):741–5.
68. Lenferink A, van der Palen J, Effing T. The role of social support in improving chronic obstructive pulmonary disease self-management, vol. 12. In: Taylor & Francis; 2018. p. 623.
69. Reardon JZ, Lareau SC, ZuWallack R. Functional status and quality of life in chronic obstructive pulmonary disease. Am J Med. 2006;119(10):32–7.
70. Locke EA, Latham GPJ. New directions in goal-setting theory. Curr Dir Psychol Sci. 2006;15(5):265–8.
71. Sullivan AN, Lachman ME. Behavior change with fitness technology in sedentary adults: a review of the evidence for increasing physical activity. Front Public Health. 2016;4:289.
72. Sullivan AN, Lachman ME. Behavior change with fitness technology in sedentary adults: a review of the evidence for increasing physical activity. Front Public Health. 2017;4:289.
73. Lyons EJ, Swartz MC, Lewis ZH, Martinez E, Jennings K. Feasibility and acceptability of a wearable technology physical activity intervention with telephone counseling for mid-aged and older adults: a randomized controlled pilot trial. JMIR Mhealth Uhealth. 2017;5(3):e28.
74. Robinson SA, Bisson AN, Hughes ML, Ebert J, Lachman ME. Time for change: using implementation intentions to promote physical activity in a randomised pilot trial. Psychol Health. 2019;34(2):232–54.
75. Bock B, Linke S, Napolitano M, Clark M, Gaskins R, Marcus B. Exercise initiation, adoption, and maintenance in adults: theoretical models and empirical support. In: Exploring sport and exercise psychology; 2014. p. 165–89.
76. Robinson SA, Bisson AN, Hughes ML, Ebert J, Lachman ME. Time for change: using implementation intentions to promote physical activity in a randomised pilot trial. Psychol Health. 2018:1–23.
77. Norman GJ, Zabinski MF, Adams MA, Rosenberg DE, Yaroch AL, Atienza AA. A review of eHealth interventions for physical activity and dietary behavior change. Am J Prev Med. 2007;33(4):336–45. e316.
78. Irvine AB, Gelatt VA, Seeley JR, Macfarlane P, Gau JM. Web-based intervention to promote physical activity by sedentary older adults: randomized controlled trial. J Med Internet Res. 2013;15(2):e19.
79. Mantoani LC, Rubio N, McKinstry B, MacNee W, Rabinovich RA. Interventions to modify physical activity in patients with COPD: a systematic review. Eur Respir J. 2016;48(1):69–81.
80. Cornwell EY, Waite LJ. Social disconnectedness, perceived isolation, and health among older adults. J Health Soc Behav. 2009;50(1):31–48.
81. Kantorowski A, Wan ES, Homsy D, Kadri R, Richardson CR, Moy ML. Determinants and outcomes of change in physical activity in COPD. ERJ Open Res. 2018;4(3):00054–2018.
82. Mangan JMJC. The potential for reducing asthma disparities through improved family and social function and modified health behaviors. Chest. 2007;132(5):789S–801S.

83. Nield M, Hoo GWS. Real-time telehealth for COPD self-management using skype™. COPD: J Chron Obstruct Pulmon Dis. 2012;9(6):611–9.
84. Nguyen HQ, Donesky-Cuenco D, Wolpin S, et al. Randomized controlled trial of an Internet-based versus face-to-face dyspnea self-management program for patients with chronic obstructive pulmonary disease: pilot study. J Med Internet Res. 2008;10(2):e9.
85. Thorpe O, Johnston K, Kumar S. Barriers and enablers to physical activity participation in patients with COPD: a systematic review. J Cardiopulm Rehabil Prev. 2012;32(6):359–69.
86. Thorpe O, Kumar S, Johnston K. Barriers to and enablers of physical activity in patients with COPD following a hospital admission: a qualitative study. Int J Chron Obstruct Pulmon Dis. 2014;9:115–28.
87. Tabak M, Vollenbroek-Hutten MM, van der Valk PD, van der Palen J, Hermens HJ. A telerehabilitation intervention for patients with Chronic Obstructive Pulmonary Disease: a randomized controlled pilot trial. Clin Rehabil. 2014;28(6):582–91.
88. van der Weegen S, Verwey R, Spreeuwenberg M, Tange H, van der Weijden T, de Witte L. It's LiFe! mobile and web-based monitoring and feedback tool embedded in primary care increases physical activity: a cluster randomized controlled trial. J Med Internet Res. 2015;17(7):e184.
89. Wan ES, Kantorowski A, Homsy D, et al. Promoting physical activity in COPD: insights from a randomized trial of a web-based intervention and pedometer use. Respir Med. 2017;130:102–10.
90. Danilack VA, Weston NA, Richardson CR, Mori DL, Moy ML. Reasons persons with COPD do not walk and relationship with daily step count. COPD. 2014;11(3):290–9.
91. Grady PA, Gough LL. Self-management: a comprehensive approach to management of chronic conditions. Am J Public Health. 2014;104(8):e25–31.
92. Wagner EH, Austin BT, Davis C, Hindmarsh M, Schaefer J, Bonomi A. Improving chronic illness care: translating evidence into action. Health Aff. 2001;20(6):64–78.
93. Barberan-Garcia A, Vogiatzis I, Solberg H, et al. Effects and barriers to deployment of telehealth wellness programs for chronic patients across 3 European countries. Respir Med. 2014;108(4):628–37.
94. Venkatesh V, Thong JY, Xu X. Unified theory of acceptance and use of technology: a synthesis and the road ahead. J Assoc Inf Syst. 2016;17(5):328–76.
95. Martinez CH, Moy ML, Nguyen HQ, et al. Taking Healthy Steps: rationale, design and baseline characteristics of a randomized trial of a pedometer-based internet-mediated walking program in veterans with chronic obstructive pulmonary disease. BMC Pulm Med. 2014;14:12.
96. Moy ML, Collins RJ, Martinez CH, et al. An internet-mediated pedometer-based program improves health-related quality-of-life domains and daily step counts in COPD: a randomized controlled trial. Chest. 2015;148(1):128–37.
97. Moy ML, Martinez CH, Kadri R, et al. Long-term effects of an internet-mediated pedometer-based walking program for chronic obstructive pulmonary disease: randomized controlled trial. J Med Internet Res. 2016;18(8):e215.
98. Moy ML, Weston NA, Wilson EJ, Hess ML, Richardson CR. A pilot study of an internet walking program and pedometer in COPD. Respir Med. 2012;106(9):1342–50.
99. Teylan M, Kantorowski A, Homsy D, Kadri R, Richardson C, Moy M. Physical activity in COPD: minimal clinically important difference for medical events. Chron Respir Dis. 2019;16:1479973118816424.
100. Demeyer H, Louvaris Z, Frei A, et al. Physical activity is increased by a 12-week semiautomated telecoaching programme in patients with COPD: a multicentre randomised controlled trial. Thorax. 2017;72(5):415–23.
101. Nguyen HQ, Gill DP, Wolpin S, Steele BG, Benditt JO. Pilot study of a cell phone-based exercise persistence intervention post-rehabilitation for COPD. Int J Chron Obstruct Pulmon Dis. 2009;4:301–13.

102. Vorrink SN, Kort HS, Troosters T, Zanen P, Lammers JJ. Efficacy of an mHealth intervention to stimulate physical activity in COPD patients after PR. Eur Respir J. 2016;48(4):1019–29.
103. Carroll JK, Moorhead A, Bond R, LeBlanc WG, Petrella RJ, Fiscella KJ. Who uses mobile phone health apps and does use matter? A secondary data analytics approach. J Med Internet Res. 2017;19(4):e125.
104. Fox S, Duggan M. Mobile health 2012. Pew internet and American life project. In: Washington, DC: Pew Research Center; 2012.
105. Kontos E, Blake KD, Chou W-YS, Prestin AJ. Predictors of eHealth usage: insights on the digital divide from the Health Information National Trends Survey 2012. J Med Internet Res. 2014;16(7):e172.
106. McCully SN, Don BP, Updegraff JA. Using the Internet to help with diet, weight, and physical activity: results from the Health Information National Trends Survey (HINTS). J Med Internet Res. 2013;15(8):e148.
107. McAuley A. Digital health interventions: widening access or widening inequalities? Public Health. 2014;12(128):1118–20.
108. Patel MS, Asch DA, Volpp KG. Wearable devices as facilitators, not drivers, of health behavior change. JAMA. 2015;313(5):459–60.
109. Moy ML, Garshick E, Matthess KR, Lew R, Reilly JJ. Accuracy of a uniaxial accelerometer in chronic obstructive pulmonary disease. J Rehabil Res Dev. 2008;45(4):611.
110. Gurupur VP, Wan TT. Challenges in implementing mHealth interventions: a technical perspective. mHealth. 2017;3:32.
111. Koreny M, Demeyer H, Arbillaga-Etxarri A, et al. Determinants of study completion and response to a 12-month physical activity intervention in COPD. In: Eur Respiratory Soc; 2018.
112. Orme MW, Weedon AE, Saukko PM, et al. Findings of the Chronic Obstructive Pulmonary Disease-Sitting and Exacerbations Trial (COPD-SEAT) in reducing sedentary time using wearable and mobile technologies with educational support: randomized controlled feasibility trial. JMIR Mhealth Uhealth. 2018;6(4):e84.
113. Burkow TM, Vognild LK, Johnsen E, Bratvold A, Risberg MJ, Making D. Promoting exercise training and physical activity in daily life: a feasibility study of a virtual group intervention for behaviour change in COPD. BMC Med Inform Decis Mak. 2018;18(1):136.
114. Cox NS, McDonald CF, Alison JA, et al. Telerehabilitation versus traditional centre-based PR for people with chronic respiratory disease: protocol for a randomised controlled trial. BMC Pulm Med. 2018;18(1):71.
115. Chen Y-W, Hunt MA, Campbell KL, Peill K, Reid WD. The effect of Tai Chi on four chronic conditions—cancer, osteoarthritis, heart failure and chronic obstructive pulmonary disease: a systematic review and meta-analyses. Br J Sports Med. 2016;50(7):397–407.
116. Donesky D, Selman L, McDermott K, Citron T, Howie-Esquivel J, Medicine C. Evaluation of the feasibility of a home-based TeleYoga intervention in participants with both chronic obstructive pulmonary disease and heart failure. J Altern Complement Med. 2017;23(9):713–21.
117. Moy ML, Wayne PM, Litrownik D, et al. Long-term Exercise after PR (LEAP): design and rationale of a randomized controlled trial of Tai Chi. Contemp Clin Trials. 2015;45:458–67.
118. Liu W, Wang C, Lin H, et al. Efficacy of a cell phone-based exercise programme for COPD. Eur Respir J. 2008;32(3):651–9.
119. Voncken-Brewster V, Tange H, de Vries H, Nagykaldi Z, Winkens B, van der Weijden T. A randomized controlled trial evaluating the effectiveness of a web-based, computer-tailored self-management intervention for people with or at risk for COPD. Int J Chron Obstruct Pulmon Dis. 2015;10:1061.
120. Arbillaga-Etxarri A, Gimeno-Santos E, Barberan-Garcia A, et al. Long-term efficacy and effectiveness of a behavioural and community-based exercise intervention (Urban Training) to increase physical activity in patients with COPD: a randomised controlled trial. Eur Respir J. 2018;52(4):1800063.

121. Park SA, Kim JYA, Lee JCA, et al. Mobile phone app-based PR for chemotherapy-treated patients with advanced lung cancer: pilot study. JMIR Mhealth Uhealth. 2019;7(2):e11094. (2291-5222 (Print)).
122. Choi J, Hergenroeder AL, Burke L, et al. Delivering an in-home exercise program via telerehabilitation: a pilot study of Lung Transplant Go (LTGO). Int J Telerehabil. 2016;8(2):15–26. (1945–2020 (Print)).
123. Mendoza L, Horta P, Espinoza J, Aguilera M, Balmaceda N, Castro A, Ruiz M, Díaz O, Hopkinson NS. Pedometers to enhance physical activity in COPD: a randomised controlled trial. Eur Respir J. 2015;45(2):347–54