J Behav Med (2019) 42:1082–1090
https://doi.org/10.1007/s10865-019-00042-3

A web-based physical activity intervention benefits persons with low self-efficacy in COPD: results from a randomized controlled trial

Stephanie A. Robinson[1] · Stephanie L. Shimada[1,2] · Karen S. Quigley[1,3] · Marilyn L. Moy[4,5]

Received: December 18, 2018 / Accepted: April 4, 2019 / Published online: April 12, 2019

Abstract Promoting physical activity (PA) is of top priority in chronic obstructive pulmonary disease (COPD). This study examines the influence of an internet-delivered intervention on the relationship between exercise self-efficacy and changes in PA, physical health, and exercise capacity in COPD. 112 U.S. Veterans with COPD were randomized to either a comparison (pedometer alone) or an intervention group (pedometer plus access to an internet-mediated PA intervention). There was a significant interaction between baseline exercise self-efficacy and randomization group on change in PA. In the comparison group, there was a significant relationship between higher baseline exercise self-efficacy and greater change in PA, whereas in the intervention group, improvements in PA were independent of level of baseline self-efficacy. Similar patterns were found with physical health and exercise capacity as outcomes. The use of an internet-mediated intervention significantly benefited persons with COPD who had low baseline self-efficacy to increase PA and physical health. *Clinical trial registration* The randomized clinical trial was registered on ClinicalTrials.gov (NCT01772082).

Keywords Chronic obstructive pulmonary disease · COPD · Self-efficacy · Physical activity · Randomized trial · Technology

Introduction

Increasing physical activity (PA) is recommended in patients with Chronic Obstructive Pulmonary Disease (COPD) to optimize health outcomes and reduce healthcare costs (Vogelmeier et al., 2017; Watz et al., 2014). Independent of lung function, persons with COPD who walk the most have the lowest risk of acute exacerbations and hospitalizations, and the lowest rates of healthcare utilization and death (Moy et al., 2013, 2016; Nguyen et al., 2014; Watz et al., 2014). Current therapies to increase PA in COPD populations are limited. Although pulmonary rehabilitation programs are the standard of care and improve exercise *capacity* in persons with COPD, barriers remain with promoting *engagement* in daily PA (Cindy Ng et al., 2012).

Reduced lung function and exercise capacity limit PA, but physical inactivity in COPD is also influenced by psychosocial determinants of behavior, such as self-efficacy (McAuley & Blissmer, 2000; McAuley et al., 2011). *Self-efficacy* refers to confidence about one's own ability to engage in a specific behavior. Those with higher self-efficacy beliefs perceive obstacles as surmountable, via enhanced self-management skills and persistent effort, whereas those lower in self-efficacy easily perceive such obstacles as insurmountable (Bandura, 2004). Self-efficacy beliefs are posited to influence behavior directly through the development and use of self-regulatory behaviors (Bandura, 1986). The influence of self-efficacy on engagement in healthy behaviors has been previously documented. For example, a previous meta-analysis found consistent evidence that self-efficacy predicted whether or not one

✉ Stephanie A. Robinson
stephanie.robinson5@va.gov

1 Edith Nourse Rogers Memorial Veterans Hospital, Bedford, MA, USA

2 School of Public Health, Boston University, Boston, MA, USA

3 Northeastern University, Boston, MA, USA

4 VA Boston Healthcare System, Boston, MA, USA

5 Harvard Medical School, Boston, MA, USA

would abstain from or resume smoking (Gwaltney et al., 2009). In diabetes, baseline self-efficacy predicted adherence to diabetes self-management behaviors (Nakahara et al., 2006) and engagement in PA (Luszczynska et al., 2011). Technology-based interventions have the potential to provide convenient and accessible means to enhance exercise self-efficacy, and to educate and motivate people in their efforts to make healthy lifestyle changes (Lewis et al., 2017).

We developed a web-based, pedometer-mediated PA intervention, and showed that it significantly increases daily steps and health-related quality of life (HRQL) in patients with COPD (Moy et al., 2015). The current study, Every Step Counts (ESC), extends our previous work by assessing psychosocial variables such as self-efficacy that can be used to examine the relationship between this psychosocial correlate of behavior, and the effect of the web-based intervention on PA (Wan et al., 2017). Wan and colleagues have previously reported the primary results of ESC (Wan et al., 2017). In sum, ESC helped participants maintain PA levels in the face of environmental challenges, such as varying seasons and declining temperatures (Wan et al., 2017). Although there were no documented changes in self-efficacy post-intervention compared to baseline for either the comparison or intervention group (Wan et al., 2017), we hypothesized that baseline self-efficacy, before participants used ESC, is important in determining their engagement in PA and response to ESC. In this secondary analysis, we examined whether a web-based PA intervention would facilitate participant engagement in PA regardless of participants' baseline self-efficacy. We also explored the impact of ESC on the relationship between baseline self-efficacy and patient self-reported physical health and exercise capacity.

Methods

We used data from the ESC study, a single-site randomized controlled trial (RCT) which compared an intervention that included a pedometer plus a website that provided goal setting, feedback, motivational and educational content, and social support (intervention) to a pedometer alone (comparison) (Wan et al., 2017). A previous publication, which adhered to the Consolidated Standards of Reporting Trials (CONSORT) checklist for reporting randomized trials, described in detail the research methods and results for the primary outcome of daily step count (Wan et al., 2017). The protocol was approved by the VA Boston Healthcare System Committee on Human Research, and we obtained written informed consent. The randomized clinical trial was registered on ClinicalTrials.gov (NCT01772082).

Participants

Data were collected from 112 Veteran participants (53 comparison, 59 intervention) enrolled from the general pulmonary clinics at VA Boston. Participants were eligible for participation if they were at least 40 years old, diagnosed with COPD, emphysema or chronic bronchitis ($FEV_1/FVC < 0.70$), had a history of smoking, able to walk at least 1 block, and had access to a computer with internet or were willing to come to VA to use a computer at least once a week. Participants were not eligible if they had a COPD exacerbation within the previous month, were not able to walk, or recently completed a pulmonary rehabilitation program within 3 months prior to the enrollment date. Over half of the patients (56.3%) were classified as GOLD (Global Initiative for Chronic Obstructive Lung Disease) Stage 2 and 85.7% had no exacerbations within the past year (Table 1). See Wan et al. (2017) for a more detailed description regarding inclusion/exclusion criteria.

Intervention

Eligible participants were randomized with blocking stratified by season and baseline 6-min walk test (6MWT) distance to either the intervention or the comparison group for 3 months. See Wan et al. (2017) for allocation information. Participants in the intervention group were given access to the website and were asked to wear the pedometer daily during all waking hours and to upload their step counts weekly. The website provided content to enhance motivation, self-efficacy, disease knowledge, and self-management. Participants in the intervention group received individualized step-count goals every week based on their most recently uploaded step-count data or previously set step-count goal, as well as graphical displays of step count feedback. The website contained an online community to foster social support, as well as motivational messages developed by pulmonologists and behavioral psychologists to address the specific needs of persons with COPD, and educational content that mirrors topics commonly taught in the education component of conventional pulmonary rehabilitation. The content provided was both general and disease-specific. See Wan et al. (2017) for more details regarding the intervention.

Participants in the comparison group were given a pedometer and written materials about exercise at the beginning of the study but were not assigned step-count goals. Like the intervention group, they were asked to wear the pedometer daily while awake and to upload their step counts through the website. For those in the comparison group, the website had no content except that it indicated the study week.

Table 1 Participant characteristics by randomization group

	Total (N = 112)	Intervention (n = 59)	Comparison (n = 53)
Age	68.78 ± 8.43	68.66 ± 8.93	68.91 ± 7.94
Education			
<High school	9.82%	6.78%	13.21%
High school	16.07%	15.25%	16.98%
Some college	50.89%	49.15%	52.83%
>Bachelor's degree	23.21%	28.81%	16.98%
FEV_1 %	62.37 ± 21.34	60.01 ± 20.86	65.01 ± 21.76
GOLD stage			
I	17.89%	13.56%	22.64%
II	56.25%	59.32%	52.83%
III	20.54%	20.34%	20.75%
IV	5.36%	6.78%	3.77%
% < 1 Exacerbations (past year)	85.71%	84.75%	86.79%
Enrollment season			
Winter	11.61%	8.47%	15.09%
Spring	31.25%	32.20%	30.19%
Summer	25.89%	22.03%	30.19%
Fall	31.25%	37.29%	24.53%
Baseline Self-efficacy	62.71 ± 22.55	59.7 ± 23.46	66.06 ± 21.22
Baseline PA (steps per day)	3636 ± 2655	3408 ± 2753	3881 ± 2549
Baseline PCS	38.18 ± 9.61	38.73 ± 8.95	37.57 ± 10.35
Baseline 6MWT (meters)	387 ± 82	382 ± 90	393 ± 72
Δ Self-efficacy	− 3.33 ± 21.53	− 0.85 ± 21.86	− 6.08 ± 21.01
Δ PA (steps per day)	206 ± 1955	440 ± 1820	− 66 ± 2088
Δ PCS	0.74 ± 7.21	1.4 ± 6.51	0.01 ± 7.91
Δ 6MWT (meters)	0.15 ± 51.5	− 0.63 ± 55.1	1.02 ± 47.7

Mean ± 1 Standard Deviation. FEV_1 % = Forced expiratory volume in the first second. PA = Physical Activity. PCS = VR-36 Physical Component Score. 6MWT = 6-min walk test. Δ = Change from baseline (Week 1) to end of intervention (Week 13)

Measures

Exercise regulatory self-efficacy

Self-efficacy was measured with the Exercise Self-regulatory Efficacy scale which has been shown to be reliable and valid in COPD (Davis et al., 2007). This scale has 16 items that ask participants to report how confident they are that they could continue to exercise regularly (3 times a week for 20 min) when faced with certain situations (e.g., weather is bothering me, feel short of breath when exercising, too busy with other activities, etc.). Responses range from 0% (not at all confident) to 100% (highly confident). Self-efficacy was measured in all participants at baseline and end-of-study.

Physical activity

PA was measured with daily step counts. Daily step counts were assessed objectively using the Omron HJ-720 ITC pedometer, which has been previously validated in COPD (Danilack et al., 2014). We considered 'valid wear days' those days on which the device was worn by the participants for greater than 8 h and recorded at least 100 steps. Baseline PA was measured with average daily step count across 7 days prior to randomization.

Patients may be more motivated to be more active when they are able to see their steps and receive feedback. Therefore, to obtain a more accurate estimate of their baseline activity level before the start of the intervention, participants could not see their step-count data and received no step-count feedback during these baseline 7 days. All patients were able to see their daily step counts after the baseline 7 days, which were displayed on the face of the pedometer in real time. Following randomization, daily step counts were averaged each week if the subject had at least 3 valid wear days that week. The difference in step counts was calculated by subtracting the average daily step count at baseline from the average daily step count at week 13.

Self-reported physical health

Self-reported physical health was assessed using the Veterans RAND 36-Item Health Survey (VR-36©) (Kazis et al., 2004). The VR-36 is adapted from the Medical Outcomes Study 36-item short form (SF-36) (Ware Jr & Sherbourne, 1992) to better represent Veterans' HRQL. The VR-36 has 8 domains that contribute to 2 summary component scores, mental and physical health. We used the physical component score (PCS). Higher scores correspond to better self-reported physical health.

Exercise capacity

Exercise capacity was assessed with maximal distance walked on the 6MWT (American Thoracic Society [ATS], 2002). The 6MWT was conducted according to ATS guidelines without a practice walk. In this assessment, patients choose their own intensity level of exercise, and therefore do not typically reach maximal exercise capacity (ATS, 2002). However, as most daily activities are performed at submaximal levels, the 6MWT, rather than the maximal cardiopulmonary exercise test, may be a better reflection of functional exercise capacity for daily physical activities (ATS, 2002).

Covariates

Age, education, forced expiratory volume in the first second (FEV_1) % predicted, and season of enrollment were included in the analyses as covariates. Education was included as a covariate due to its well-documented relationship with self-efficacy (Murray et al., 2012). Education was coded categorically: (1) did not complete high school, (2) completed high school, (3) some college or post-high school education or training, or (4) bachelor's degree or higher. FEV_1 % predicted was assessed using an Eaglet spirometer (nSpire Health, Inc., Longmont, CO, USA) according to ATS guidelines (Miller et al., 2005). Season of enrollment was determined based on when 4 or more days of the baseline week fell into the following calendar months: winter (December–February), spring (March–May), summer (June–August), or fall (September–November).

Technology use

To characterize the cohort, at study entry we assessed participants self-reported internet use ("how often do you use the internet?") and ability ("how would you rate your ability to use the internet?"). At the end of the study, participants in the intervention group reported on their experience using the study technology (website and pedometer). Questions included: "I had trouble logging into the website", "I had difficulty uploading step-counts to the website", "I had difficulty using the pedometer to obtain step-count feedback". We also examined how frequently patients in the intervention group logged into the website.

Statistical analyses

Data analyses were conducted in SAS v9.4 (Cary, NC). We calculated the mean and standard deviation for all variables at baseline, both overall and by randomization group. We also calculated change scores from baseline to end-of-study for exercise self-efficacy and the dependent variables (PA, PCS, and 6MWT). Preliminary analyses were conducted to characterize the sample (means, standard deviations, and frequencies) and explore zero-order correlations among the main study variables. The main hypotheses of this study were tested using generalized linear models (PROC GLM) to evaluate the relationship between baseline exercise self-efficacy and these dependent variables. An interaction term between randomization group and baseline self-efficacy was included to evaluate if assignment to the ESC intervention, compared to the comparison group, differentially influenced the relationship between baseline self-efficacy and the dependent variable. To further understand any significant interaction terms, analyses of simple slopes was conducted with PROC PLM to examine the strength of the relationship between predictor (baseline self-efficacy) and dependent variable within each randomization group. Significant interactions were plotted and the simple slopes were tested for significance. A p value < 0.05 and 95% confidence interval (CI) that did not contain zero was considered statistically significant.

Results

Table 1 summarizes descriptive statistics for the sample. There were no significant differences in age between the intervention group (69 years) compared to the comparison group (69 years). There were no significant differences at baseline between the intervention and comparison group, respectively, in education (49.15% vs. 52.83% completed some college or post-high school education or training), FEV_1 % predicted (60.01% vs. 65.01%), season of enrollment (32.2% vs. 30.2% enrolled in spring), exercise self-efficacy (59.7 vs. 60.1), average daily step count (3408 vs. 3881), PCS (38.73 vs. 37.57), or 6MWT distance (382 vs. 393 meters) (Table 1). Similarly, there was no significant difference between the intervention and comparison group in change score for exercise self-efficacy (0.85 vs.

− 6.08). Patients' usual internet use and ability was assessed before the study. The majority of patients (66.1%) reported using the internet every day and a basic (38.4%) or moderate (36.6%) ability to use the internet. At the end of the study, 84.7% of patients in the intervention group reported no difficulty logging into the website, 67.2% reported no difficulty uploading step-counts to the website, and 79.66% reported no difficulty using the pedometer to obtain step-count feedback. We did not observe any significant differences by age (greater or equal to 68, or less than 68 years of age), or income (less than $15,000, $15,000–29,999, $30,000–$49,999, $50,000 or more). Participants logged into the website an average of 5.4 (SD = 3.05) times a month, which was higher than the expected 4 times a month based on our instructions to log in at least once a week.

Zero-order correlations across randomization groups among the study variables are reported in Table 2. Age was significantly associated with fewer baseline steps and less distance in the 6MWT. FEV_1 % predicted was significantly associated with less distance in the 6MWT. Baseline self-efficacy was significantly associated with less change in self-efficacy across the study period, and greater change in the 6MWT. Baseline steps were significantly associated with baseline 6MWT, less change in steps from baseline to follow up, and greater change in the PCS and 6MWT from baseline to follow up. Baseline PCS was significantly correlated with greater baseline 6MWT and less change in PCS to follow up. Change in steps was significantly correlated with greater change in PCS and the 6MWT, and change in PCS was significantly correlated with greater change in 6MWT. Among the intervention group, there was no significant relationship between use of the website (as measured by average number of monthly website logins) and change in exercise self-efficacy.

The intervention group increased their steps significantly more (440 steps) compared to the comparison group (− 66 steps); β = 0.83, $p = 0.006$, 95% CI [937.13, 5524.68]. There was a significant relationship between baseline self-efficacy and change in step count (β = 0.41, $p = 0.006$, 95% CI [10.40, 61.83]). There was a significant interaction between baseline exercise self-efficacy and randomization group predicting change in step count while controlling for age, education, FEV_1 % predicted, and season of enrollment, (β = − 0.73, $p = 0.016$, 95% CI [− 74.13, − 7.78]; Fig. 1). Simple slopes within each randomization group showed that in the comparison group, there was a significant positive association between higher baseline self-efficacy and greater change in daily step count (β = 36.11, $p = 0.006$). The relationship between baseline self-efficacy and change in daily step count was not significant in the intervention group (β = − 4.84, $p = 0.655$), where participants demonstrated increased daily step count independent of their baseline self-efficacy (Fig. 1 and Table 3). In other words, participants in the intervention group benefited from the intervention and increased step count regardless of their initial level of self-efficacy, whereas in the comparison group only those who had higher baseline self-efficacy increased their step count.

Similar patterns were observed for PCS (i.e., self-reported physical health) and 6MWT (i.e., exercise capacity). The intervention group showed significantly greater improvement in PCS (1.40) compared to the comparison group (0.01); β = 0.76, $p = 0.012$, 95% CI [2.45, 19.28]. There was a significant relationship between baseline self-efficacy and greater improvements in PCS (β = 0.40, $p = 0.011$, 95% CI [0.03, 0.22]). There was a significant interaction between baseline self-efficacy and randomization group predicting change in PCS (β = − 0.71, $p = 0.021$, 95% CI [− 0.27, − 0.02]; Fig. 2). Simple slopes analyses within each ran-

Table 2 Zero-order correlations of main study variables (N = 112)

	1	2	3	4	5	6	7	8	9	10
1. Age	–									
2. FEV_1 %	0.17	–								
3. Baseline Self-efficacy	− 0.04	0.10	–							
4. Baseline Steps	− 0.25*	0.05	0.15	–						
5. Baseline PCS	0.00	0.16	0.08	0.09	–					
6. Baseline 6MWT	− 0.43**	0.17	0.18	0.37**	0.31**	–				
7. Δ Self-efficacy	0.10	− 0.06	− 0.40**	0.11	− 0.09	− 0.11	–			
8. Δ Steps	0.08	− 0.06	0.18	− 0.20*	0.03	− 0.03	0.03	–		
9. Δ VR-36 PCS	0.02	0.01	0.10	0.22*	− 0.37**	0.02	0.15	0.21*	–	
10. Δ 6MWT	− 0.07	− 0.27*	0.21*	0.39**	− 0.07	− 0.12	0.10	0.25*	0.35**	–

FEV_1 % = Forced expiratory volume (in the first second) % predicted. Δ VR-36 PCS = Change in VR-36 Physical Component Summary score. Δ 6MWT = Change in 6-min Walk Test distance

*p < .05; **p < .01

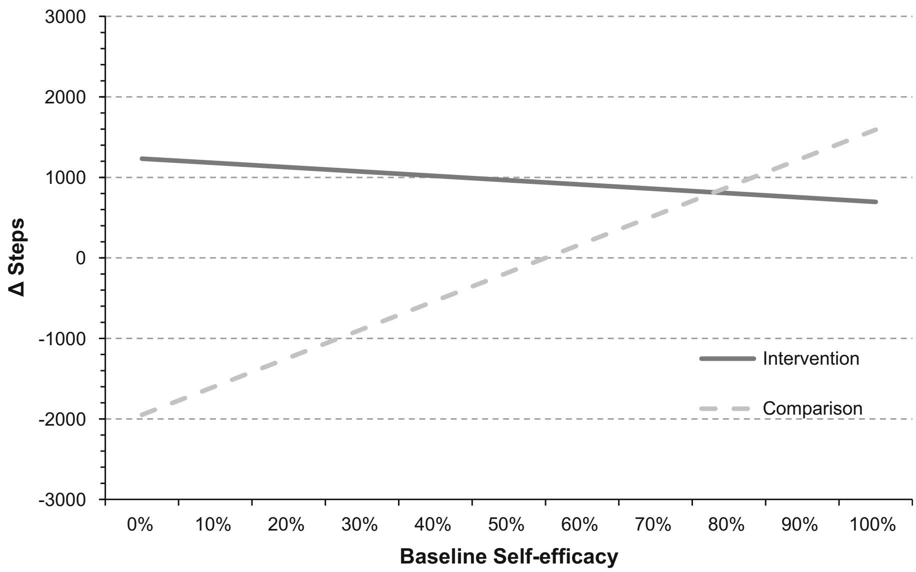

Fig. 1 The interaction between baseline self-efficacy and change in steps by randomization group controlling for FEV_1 % predicted, age, education, and season, $p = 0.016$. Simple slope analyses revealed a significant positive relationship between baseline self-efficacy and change in steps for the comparison group ($p = 0.006$) and no significant relationship between baseline self-efficacy and change in steps for the intervention group ($p = 0.655$)

Table 3 General linear model parameter estimates

Parameter	Models by dependent variable					
	Δ Steps		Δ VR-36 PCS		Δ 6MWT	
	β	*p*	β	*p*	β	*p*
Age	0.15	0.108	0.04	0.647	0.03	0.759
Education						
<High school (Reference)						
High school	− 0.12	0.407	0.02	0.877	0.19	0.165
Some college	0.03	0.842	− 0.13	0.466	0.17	0.310
>Bachelor's degree	− 0.03	0.860	− 0.16	0.330	0.05	0.745
FEV_1 %	− 0.14	0.145	− 0.04	0.710	− 0.32	0.001
Enrollment season						
Winter (Reference)						
Spring	0.09	0.546	0.16	0.321	0.03	0.853
Summer	− 0.24	0.106	− 0.06	0.696	− 0.07	0.611
Fall	− 0.19	0.210	0.11	0.477	− 0.13	0.371
Group						
Comparison (Reference)						
Intervention	0.83	0.006	0.76	0.012	0.46	0.104
Baseline Self-efficacy	0.41	0.006	0.40	0.011	0.42	0.005
Baseline Self-efficacy * Group Comparison (Reference)						
Intervention	− 0.73	0.016	− 0.15	0.021	− 0.51	0.080
Baseline Self-efficacy Slope						
For Group = Comparison	36.11	0.006	0.13	0.011	0.96	0.005
For Group = Intervention	− 4.84	0.655	− 0.02	0.597	0.20	0.461

Δ Outcome = $\beta_0 + \beta_1$(Age) + β_2(Education) + β_3(FEV_1 %) + β_4(Season) + β_5(Group) + β_6(Baseline Self-efficacy) + β_7(Group*Baseline Self-efficacy). Δ VR-36 PCS = Change in VR-36 Physical Component Summary score. Δ 6MWT = Change in 6-min walk test distance. FEV_1 % = Forced expiratory volume (in the first second) % predicted. Baseline Self-efficacy Slope represents the relationship between baseline self-efficacy and the dependent variable by randomization group

domization group revealed a significant association between higher baseline self-efficacy and greater change in PCS in the comparison group (β = 0.13, $p = 0.011$); there was no significant relationship between baseline self-efficacy and change in PCS in the intervention group (β = − 0.02, $p = 0.597$), where participants demonstrated increased self-

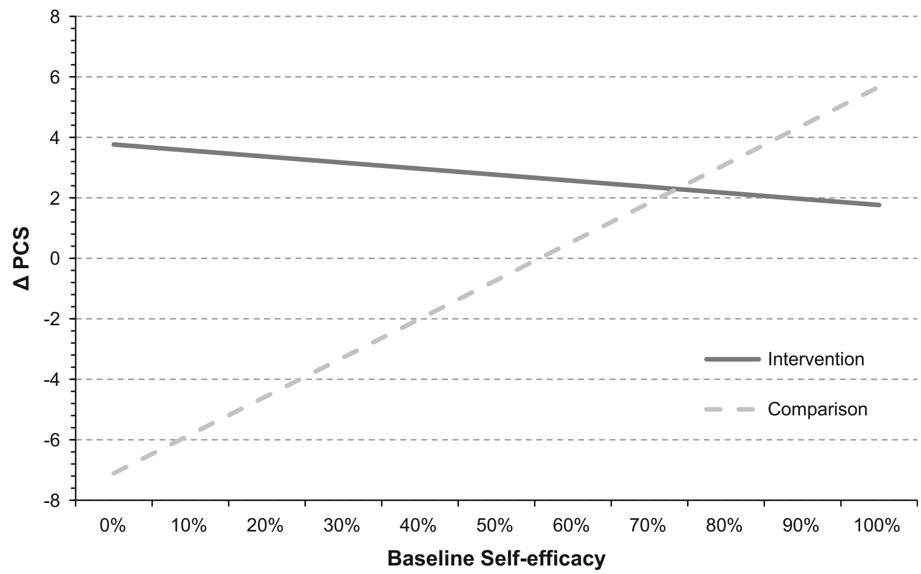

Fig. 2 The interaction between baseline self-efficacy and change in PCS (VR-12 Physical Component Score) by randomization group controlling for FEV_1 % predicted, age, education, and season, $p = 0.021$. Simple slope analyses revealed a significant positive relationship between baseline self-efficacy and change in PCS for the comparison group ($p = 0.011$) and no significant relationship between baseline self-efficacy and change in PCS for the intervention group ($p = 0.597$)

reported physical health scores regardless of baseline level of self-efficacy (Table 3).

There was no significant difference between the intervention and comparison group for change in 6MWT (β = 0.46, $p = 0.104$, 95% CI [− 9.82, 104.36]). There was a significant relationship between baseline self-efficacy and greater improvement in 6MWT (β = 0.42, $p = 0.005$, 95% CI [0.30, 1.62]). There was a trend toward a significant interaction between baseline self-efficacy and randomization group on change in 6MWT (β = − 0.51, $p = 0.080$, 95% CI [− 1.60, 0.09]). Analysis of the simple slopes revealed a similar pattern, where the comparison group again demonstrated a significant relationship between baseline self-efficacy and change in 6MWT (β = 0.96, $p = 0.005$), whereas the intervention group showed no significant relationship (β = 0.20, $p = 0.461$) (Table 3).

Discussion

Low exercise self-efficacy is associated with low PA, self-reported physical health, and exercise capacity in patients with COPD. We show that the use of a web-based pedometer-mediated PA intervention can uncouple this relationship. The current study demonstrates that ESC can increase daily PA and self-reported physical health in persons with COPD independent of their baseline level of exercise self-efficacy. As noted in the primary paper (Wan et al., 2017), this increase in PA was clinically meaningful. Specifically, those with low or high baseline self-efficacy in the intervention group increased their PA and self-reported physical health, whereas only those in the comparison group with a higher level of baseline self-efficacy increased their PA and self-reported physical health.

A similar pattern existed between baseline self-efficacy and change in exercise capacity. This relationship may be attributed to engaging in greater daily physical activity and aerobic exercise, which likely improved patients' exercise capacity—that is, those who walked more with greater intensity throughout the study were able to see significant improvements in exercise capacity. The relationship between baseline self-efficacy and change in exercise capacity was only at a trend level of significance, most likely due to the fact that ESC was primarily focused on promoting PA as the main outcome. It is possible that PA and self-reported physical health may be more easily influenced by specific components of our intervention that are focused on daily PA, whereas change in exercise capacity may require an intervention of greater intensity and longer duration.

It is promising that the web-based intervention increased PA and self-reported physical health across varying levels of baseline self-efficacy even though there was no statistically significant change in exercise self-efficacy due to the intervention (Wan et al., 2017). Interestingly, the intervention group reported less change compared to the comparison group in self-efficacy from baseline to the end of the study. It may be that the web-based intervention was able to help maintain patients' exercise regulatory self-efficacy despite possible challenges such as seasonal changes and declining temperatures. Our research demonstrates that technology-based interventions like ESC can overcome the relationship between low self-efficacy and low engagement in PA and help patients with low self-efficacy achieve higher or maintain PA goals. Understanding who would benefit the most from a web-based intervention like ESC is critical to personalizing exercise counseling. If a patient is confident in his/her ability to exercise (i.e., high self-efficacy), he/she will be likely to increase PA with a more modest intervention. On the other hand, for patients who doubt their ability to exercise, perhaps because they are worried they will become short of breath or too fatigued, enrolling them in an easily accessible, web-based intervention that can support behavior change despite their low exercise self-efficacy may enhance improvements in their rehabilitation. These findings support a 'personalized medicine' model, where physical activity interventions are not one-size fits all and not all patients require, or will benefit from, the same treatments or interventions. Some patients may not require as much support for behavior change as provided by the web-based intervention (i.e., those higher in self-efficacy), and would have increased their PA with or without the website; some patients may require a more supportive intervention to encourage behavior change. This has important implications for tailoring interventions to patients and taking self-efficacy into consideration when deciding best practices for behavior change.

There are several limitations to this work. First, this was a secondary analysis, and there may not have been sufficient power to detect significant differences in baseline self-efficacy between groups or intervention-related changes in exercise capacity. Alternatively, it is possible that we did not detect changes in self-efficacy with the specific measurement we used, although this measure has been previously used in COPD populations (Davis et al., 2007) and is considered appropriate for an exercise-related intervention. Further, this measure focused specifically on exercise self-regulatory efficacy and, in general, measurement of self-efficacy that is specific to the domain of interest provides the most sensitive assessment (Robinson et al., 2018). Indeed, the findings from this study substantiate the association between baseline self-efficacy and change in PA and self-reported physical health, and that ESC can be used to uncouple this relationship and support increased activity across varying levels of self-efficacy. However, future work should continue to investigate methods to increase baseline self-efficacy before an intervention so that all patients can begin with a higher level. We also note that the sample was mostly elderly male Veterans sampled from a single site, and thus these results may not generalize to other samples. Future research would benefit from a more balanced sample.

Unlike conventional pulmonary rehabilitation, or episodic, face-to-face exercise counseling, technology-based interventions offer a unique opportunity to deliver continuous support throughout patients' daily lives. However, the current study was not designed to examine the delivery mode of the intervention content (e.g., website vs. paper delivery methods). Future research should explore this question to evaluate best methods for intervention delivery. Additionally, we do not know if any patients in either group were concurrently using other, publicly available technology (e.g., apps) for PA. If patients were in fact using other technology to support their engagement in PA, we were still able to see significantly increased PA in the intervention group compared to the comparison group. Therefore, if patients in the comparison group were using other apps to support their engagement in PA, ESC was able to increase PA in the intervention group above and beyond other app use.

Increasing daily PA in persons with COPD is central to promoting healthier outcomes. However, optimizing one's physiological ability to exercise is not necessarily sufficient for engagement in daily PA, particularly when faced with a lack of exercise self-efficacy. Psychosocial factors like self-efficacy have a well-documented relationship to PA behavior, and given their modifiability, are potential targets for PA interventions. The current study demonstrates that a web-based, pedometer-mediated intervention helped participants to increase daily PA regardless of their initial exercise self-efficacy. Assessing a patient's self-efficacy during exercise counseling could help healthcare providers better personalize an exercise treatment plan for each patient that optimizes that individual's ability to improve their PA, self-reported physical health, and exercise capacity.

Acknowledgements We thank the Veterans who participated in this study. The views expressed in this article do not communicate an official position of the Department of Veterans Affairs.

Funding This study was funded by the Department of Veterans Affairs, Rehabilitation Research and Development Service [Career Development Award 2, F6847W (Moy); CDA2 IK2RX002165 (Wan); Merit O1150-R (Moy)], and the Department of Veterans Affairs Office of Academic Affiliations Advanced Fellowship Program in Health Services Research, the Center for Healthcare Organization and Implementation Research (CHOIR), Edith Nourse Rogers Memorial Veterans Hospital (Robinson).

Compliance with ethical standards

Conflict of interest Stephanie A. Robinson, Stephanie L. Shimada, Karen S. Quigley, and Marilyn L. Moy declare they have no conflict of interest.

Human and animal rights and Informed consent All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all patients for being included in the study.

References

American Thoracic Society. (2002). ATS statement: Guidelines for the six-minute walk test. *American Journal of Respiratory and Critical Care Medicine, 166,* 111–117. https://doi.org/10.1164/ajrccm.166.1.at1102

Bandura, A. (1986). The explanatory and predictive scope of self-efficacy theory. *Journal of Social and Clinical Psychology, 4,* 359–373.

Bandura, A. (2004). Health promotion by social cognitive means. *Health Education & Behavior, 31,* 143–164.

Cindy Ng, L. W., Mackney, J., Jenkins, S., & Hill, K. (2012). Does exercise training change physical activity in people with COPD? A systematic review and meta-analysis. *Chronic Respiratory Disease, 9,* 17–26.

Danilack, V. A., Weston, N. A., Richardson, C. R., Mori, D. L., & Moy, M. L. (2014). Reasons persons with COPD do not walk and relationship with daily step count. *COPD, 11,* 290–299. https://doi.org/10.3109/15412555.2013.841670

Davis, A. H., Figueredo, A. J., Fahy, B. F., & Rawiworrakul, T. (2007). Reliability and validity of the Exercise Self-Regulatory Efficacy Scale for individuals with chronic obstructive pulmonary disease. *Heart & Lung: The Journal of Acute and Critical Care, 36,* 205–216.

Gwaltney, C. J., Metrik, J., Kahler, C. W., & Shiffman, S. (2009). Self-efficacy and smoking cessation: A meta-analysis. *Psychology of Addictive Behaviors: Journal of the Society of Psychologists in Addictive Behaviors, 23,* 56–66. https://doi.org/10.1037/a0013529

Kazis, L. E., Miller, D. R., Clark, J. A., Skinner, K. M., Lee, A., Ren, X. S., et al. (2004). Improving the response choices on the veterans SF-36 health survey role functioning scales: Results from the Veterans Health Study. *The Journal of Ambulatory Care Management, 27,* 263–280.

Lewis, B. A., Napolitano, M. A., Buman, M. P., Williams, D. M., & Nigg, C. R. (2017). Future directions in physical activity intervention research: Expanding our focus to sedentary behaviors, technology, and dissemination. *Journal of Behavioral Medicine, 40,* 112–126. https://doi.org/10.1007/s10865-016-9797-8

Luszczynska, A., Schwarzer, R., Lippke, S., & Mazurkiewicz, M. (2011). Self-efficacy as a moderator of the planning–behaviour relationship in interventions designed to promote physical activity. *Psychology and Health, 26,* 151–166. https://doi.org/10.1080/08870446.2011.531571

McAuley, E., & Blissmer, B. (2000). Self-efficacy determinants and consequences of physical activity. *Exercise and Sport Sciences Reviews, 28,* 85–88.

McAuley, E., Szabo, A., Gothe, N., & Olson, E. A. (2011). Self-efficacy: Implications for physical activity, function, and functional limitations in older adults. *American Journal of Lifestyle Medicine, 5,* 361–369. https://doi.org/10.1177/1559827610392704

Miller, M. R., Hankinson, J., Brusasco, V., Burgos, F., Casaburi, R., Coates, A., et al. (2005). Standardisation of spirometry. *European Respiratory Journal, 26,* 319–338.

Moy, M. L., Collins, R. J., Martinez, C. H., Kadri, R., Roman, P., Holleman, R. G., et al. (2015). An internet-mediated pedometer-based program improves health-related quality-of-life domains and daily step counts in COPD: A randomized controlled trial. *Chest, 148,* 128–137. https://doi.org/10.1378/chest.14-1466

Moy, M. L., Gould, M. K., Liu, I. A., Lee, J. S., & Nguyen, H. Q. (2016). Physical activity assessed in routine care predicts mortality after a COPD hospitalisation. *ERJ Open Research, 2,* 00062. https://doi.org/10.1183/23120541.00062-2015

Moy, M. L., Teylan, M., Weston, N. A., Gagnon, D. R., & Garshick, E. (2013). Daily step count predicts acute exacerbations in a US cohort with COPD. *PLoS ONE, 8,* e60400. https://doi.org/10.1371/journal.pone.0060400

Murray, T. C., Rodgers, W. M., & Fraser, S. N. (2012). Exploring the relationship between socioeconomic status, control beliefs and exercise behavior: A multiple mediator model. *Journal of Behavioral Medicine, 35,* 63–73.

Nakahara, R., Yoshiuchi, K., Kumano, H., Hara, Y., Suematsu, H., & Kuboki, T. (2006). Prospective study on influence of psychosocial factors on glycemic control in Japanese patients with type 2 diabetes. *Psychosomatics, 47,* 240–246.

Nguyen, H. Q., Chu, L., Amy Liu, I. L., Lee, J. S., Suh, D., Korotzer, B., et al. (2014). Associations between physical activity and 30-day readmission risk in chronic obstructive pulmonary disease. *Annals of the American Thoracic Society, 11,* 695–705.

Robinson, S. A., Bisson, A. N., Hughes, M. L., Ebert, J., & Lachman, M. E. (2018). Time for change: Using implementation intentions to promote physical activity in a randomised pilot trial. *Psychology and Health, 34,* 232–254. https://doi.org/10.1080/08870446.2018.1539487

Vogelmeier, C. F., Criner, G. J., Martinez, F. J., Anzueto, A., Barnes, P. J., Bourbeau, J., et al. (2017). Global strategy for the diagnosis, management, and prevention of chronic obstructive lung disease 2017 report. GOLD Executive Summary. *American Journal of Respiratory and Critical Care Medicine, 195,* 557–582. https://doi.org/10.1164/rccm.201701-0218pp

Wan, E. S., Kantorowski, A., Homsy, D., Teylan, M., Kadri, R., Richardson, C. R., et al. (2017). Promoting physical activity in COPD: Insights from a randomized trial of a web-based intervention and pedometer use. *Respiratory Medicine, 130,* 102–110. https://doi.org/10.1016/j.rmed.2017.07.057

Ware, J. E., Jr., & Sherbourne, C. D. (1992). The MOS 36-item short-form health survey (SF-36): I. Conceptual framework and item selection. *Medical Care, 30,* 473–483.

Watz, H., Pitta, F., Rochester, C. L., Garcia-Aymerich, J., ZuWallack, R., Troosters, T., et al. (2014). An official European Respiratory Society statement on physical activity in COPD. *European Respiratory Journal, 44,* 1521–1537.