

Cost Savings Associated With a Web-Based Physical Activity Intervention for COPD

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Chronic obstructive pulmonary disease (COPD) is a leading cause of mortality worldwide.¹ It is a chronic disease often accompanied by acute exacerbations, which are defined as acute worsening of respiratory symptoms with significant adverse consequences for patients.²⁻⁴ Acute exacerbations vary in severity, with more severe exacerbations requiring hospitalization, where costs increase substantially.⁵ In 2010, the cost of COPD in the United States was estimated to be nearly \$50 billion, including \$30 billion in direct health care costs,⁶ which are primarily driven by acute exacerbations and hospitalizations.⁵ Acute exacerbations result in poorer health-related quality of life,⁷ a faster decline in lung function,⁸ and increased mortality.⁹ Reducing the risk of acute exacerbation is a primary goal of COPD management.¹⁰ It is critical to implement innovative measures that can reduce the incidence of hospitalizations and acute exacerbations among patients with COPD.¹¹

Regular physical activity is recommended for all individuals with COPD¹² because it is associated with better COPD-related outcomes, including decreased risk of acute exacerbations.¹³⁻¹⁵ Technology-based platforms are increasingly being recognized as a promising approach to increase physical activity and support COPD self-management.^{16,17} This increased interest in technology stems from the ever-growing ubiquity of activity monitors to directly measure physical activity parameters such as daily step counts, recognition of the many barriers patients face to accessing in-person interventions and programs, and data supporting the idea that every step counts for COPD health outcomes.^{15,18-20} Technology-based health care services provide easily accessible programs²¹⁻²³ that can effectively increase physical activity, improve COPD outcomes, and decrease risk of acute exacerbations.^{24,25} However, clinical uptake of such technology-based services has been slower than anticipated, in part due to ineffective implementation.²⁶ A recent review suggests that future effective implementation strategies for technology-based services must critically consider cost.²⁶

Results of several trials have demonstrated the efficacy of a pedometer-based, web-mediated physical activity intervention for COPD to significantly increase daily physical activity at a clinically

ABSTRACT

OBJECTIVE: To estimate the cost savings associated with a pedometer-based, web-mediated physical activity intervention in a cohort of US veterans with chronic obstructive pulmonary disease (COPD).

STUDY DESIGN: Economic analysis.

METHODS: We constructed a decision tree from the health care system perspective incorporating adjusted relative risk of a pedometer-based, web-mediated intervention for COPD-related acute exacerbations, acute exacerbation-related costs (ie, emergency department visits and hospitalizations), and intervention-related costs. Total COPD-related costs were estimated per patient across 12 months. Probabilistic sensitivity analysis with Monte Carlo simulation was used to estimate uncertainty in the model findings.

RESULTS: In the deterministic (base case) model, the model estimated costs to be \$4236 per participant who used the pedometer-based, web-mediated intervention compared with \$7913 per participant in the control group (estimated \$3677 saved in 1 year compared with the control group). The model findings were robust to probabilistic sensitivity analysis, with a difference in mean costs of \$4582 (95% probability interval, \$4084-\$5080; $P < .001$). Cost savings in the model were driven by the adjusted relative risk of the web-based intervention, probability of a COPD-related acute exacerbation, rate of hospitalization, probability of hospitalization, and cost of hospitalization.

CONCLUSIONS: A pedometer-based, web-mediated physical activity intervention yielded substantial cost savings. Increased implementation of the intervention could markedly reduce the economic burden of COPD for payers and patients.

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TAKEAWAY POINTS

- ▶ Promoting physical activity in patients with chronic obstructive pulmonary disease (COPD) reduces acute exacerbations, a leading cost driver in COPD.
- ▶ Reducing acute exacerbations is a primary objective of COPD management.
- ▶ Evaluating cost savings associated with effective interventions is important for future implementation considerations.
- ▶ This analysis modeled costs associated with use of a pedometer-based, web-mediated physical activity intervention compared with a pedometer-only control group for COPD management.
- ▶ From the health care payer perspective, this cost model estimates that use of the web-based physical activity intervention saved \$3677 compared with use of a pedometer alone.

meaningful level.^{18,20,24,27-31} A recent examination of intervention-related changes during a 12-month follow-up period found a significantly reduced risk of acute exacerbations compared with the pedometer-only control group.²⁴ Given the evidence that the pedometer-based, web-mediated physical activity intervention may reduce risk of COPD-related acute exacerbations, we sought to assess cost savings associated with this intervention. We developed an economic model incorporating clinical trial effectiveness data (ie, significantly reduced risk of COPD acute exacerbations) and costs associated with the intervention and acute exacerbations to assess cost savings associated with use of this pedometer-based, web-mediated physical activity intervention.

METHODS

Intervention Study Design

This was a retrospective, post hoc cost-benefit analysis of a randomized controlled trial conducted from the health care payer perspective. Details of the design of the trial, Every Step Counts (ClinicalTrials.gov registration number NCT01772082), have been reported.^{24,30} Patients included in the Every Step Counts trial were US veterans enrolled from the pulmonary clinics at the Veterans Affairs Boston Healthcare System from 2012 to 2016 who were aged at least 40 years, had 10 or more pack-years of smoking, had a clinical diagnosis of COPD (a ratio of forced expiratory volume in the first second of expiration to forced vital capacity < 0.70 or emphysema on a clinical chest CT), and had access to the internet. More detailed inclusion and exclusion criteria have been reported.³⁰ In total, 109 participants were randomized (1:1) to 1 of 2 arms: (1) a pedometer-based, web-mediated physical activity intervention (intervention; n = 57) or (2) a pedometer alone (control; n = 52). The website was a multicomponent intervention based on the theory of self-regulation to encourage behavior change.³² The website synced with a pedometer. An automated algorithm provided personalized and iterative daily step goals based on whether the participant met their daily step count goal the previous week. The website also included motivational and educational messages and an online forum to provide social support. The website content has been described in earlier studies.^{18,27-30} Participants were encouraged to use the pedometer and/or website (depending on

randomization group) for 3 months, with a 12-month follow-up period.

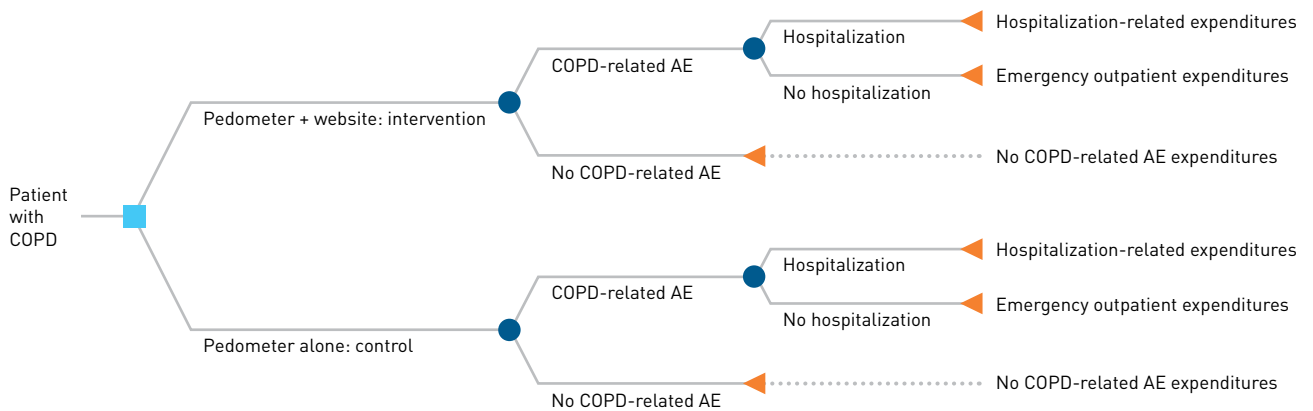
Parameters

The cost-benefit model included the effect modifier (relative risk) of the web-based intervention on the number of COPD-related acute exacerbations relative to the pedometer-alone control group ($rrAEi = 0.51$). This parameter was derived from a multivariable zero-inflated Poisson model of the trial data, adjusted for forced expiratory volume in the first second of

expiration percentage predicted, smoking status, number of acute exacerbations in the year before enrollment, and season of enrollment.²⁴ Acute exacerbations were first captured via self-report by the study participants, then verified via medical record review. If the participant could not be reached by telephone after at least 3 attempts, acute exacerbation assessment was conducted using medical record review alone. Acute exacerbations were then adjudicated by at least 2 study personnel (including a pulmonary physician), with a third adjudicator if there were any disagreements. Acute exacerbations were assessed prospectively after enrollment during the 3-month trial and over a 12-month follow-up period, totaling 15 months. Acute exacerbations were defined as a new or increased respiratory symptom with more than 2 of the following criteria: increased cough, sputum, wheezing, dyspnea, or chest tightness for more than 3 days requiring antibiotics or new/increased systemic steroid use. Acute exacerbations were considered distinct events if courses of oral corticosteroid, antibiotics, or COPD-related hospitalizations were separated by more than 14 days.²⁴ The probability, in the absence of any intervention, of a participant with COPD experiencing at least 1 acute exacerbation with hospitalization or an emergency visit without hospitalization across 12 months was defined as pAE . The probability that the acute exacerbation resulted in hospitalization was defined as $pHosp$. The rate of hospitalizations was defined as $rHosp$, and the ratio of emergency visits without hospitalization to hospitalizations for acute exacerbations was defined as $raER$. Parameters pAE , $pHosp$, $rHosp$, and $raER$ were estimated from a similar US veteran sample.¹⁵

Costs associated with acute exacerbations were estimated from the Medical Expenditure Panel Survey.³³ We extracted the total cost per event for nonadmission emergency visits and hospital visits (inclusive of costs for initial emergency visits) with associated COPD *International Classification of Diseases, Tenth Revision, Clinical Modification* diagnostic coding from the Inpatient and Emergency Room event files for the calendar year 2018. We used the respondent weighting, clustering, and stratification variables for calculation of mean emergency and inpatient visit costs with Taylor-series linearized standard errors. $cHosp$ refers to the cost of an acute exacerbation that resulted in hospitalization, and cER refers to the cost of an acute exacerbation that required emergency care but did not result in hospitalization.

FIGURE 1. Decision Tree Model for COPD-Related Acute Exacerbations Following Intervention Assignment*



AE, acute exacerbation; COPD, chronic obstructive pulmonary disease.
 *Hospitalization-related expenditures are inclusive of initial emergency visits.

Finally, the model included estimated intervention costs, which included a pedometer (Omron Corporation) (*cPed*) and a Wi-Fi-enabled device that would allow the participants to access the web-based intervention³⁴ (*cDevice*). The original trial used the Omron pedometer.³⁰ Development costs for the website, including the educational and motivational content, were not included in the model because these have already been incurred and are “sunk” costs.

Analyses

This analysis is a cost-benefit model of participants with COPD that compares estimated cost per participant who used a pedometer-based, web-mediated physical activity intervention with cost per participant who used a pedometer only (control). Using a decision model (Figure 1), the probability of the occurrence or absence of an acute exacerbation and the probability that the acute exacerbation resulted in an emergency visit without hospitalization or with hospitalization was determined based on prespecified model parameters. The costs for each branch are the summed expected values for each terminal node.³⁵ The decision tree was created using specialized validated software (TreePlan Decision Tree Add-in for Excel [TreePlan Software]). The formulas used in the decision model to estimate the cost per participant for each arm (intervention and control) are specified later herein. We assume that exacerbation-related costs are identical in the 2 arms. The intervention arm includes the adjusted relative risk of a COPD acute exacerbation attributable to the intervention compared with the control (*rrAEi*) and the cost of a Wi-Fi-enabled device required to access the website (*cDevice*). Cost savings attributed to the intervention were estimated as the difference in cost per participant between the intervention and control arms. We use a 12-month time horizon and a health care system perspective for costs. The cost formulas are as follows:

$$Cost_{Intervention} = cDevice + cPed + rrAEi \times pAE \times (pHosp \times rHosp \times cHosp + pHosp \times rHosp \times raER \times cER)$$

$$Cost_{Control} = cPed + pAE \times (pHosp \times rHosp \times cHosp + pHosp \times rHosp \times raER \times cER)$$

A series of probabilistic sensitivity analyses were run to understand the relative effect and uncertainty of the different parameters. We ran a Monte Carlo simulation with 1000 iterations to evaluate the relative impact of probabilistic variations in the model. Iterations were imputed into a 2-tailed *t* test (SAS version 9.4 [SAS Institute Inc]) to test for a significant difference between the estimated cost per participant enrolled in the intervention compared with the control. We ran a 1-way sensitivity analysis (SensIt Add-in for Excel [TreePlan Software]) to estimate how the model’s output depends on specified input variable ranges. In addition, we modeled the deterministic cost savings per participant across varying preventive effects of the intervention on COPD-related acute exacerbations. We defined the prevention of acute exacerbations as $1 - rrAEi$, ranging from 0% (ie, the intervention prevented the same amount of COPD acute exacerbations compared with the control) to 100% (the intervention reduced risk of exacerbations by 100% compared with the control).

RESULTS

Model parameters are displayed in the Table.^{15,24,33} The decision model estimated costs from the health care payer perspective per participant in each arm, accounting for all model parameters. From the decision tree model, 12-month costs at the base case for participants using the pedometer-based, web-mediated intervention were \$4236 per participant, relative to \$7913 per participant enrolled in the control group, yielding a cost savings of \$3677 per participant. Costs per participant who used the intervention were 46.5% lower than costs

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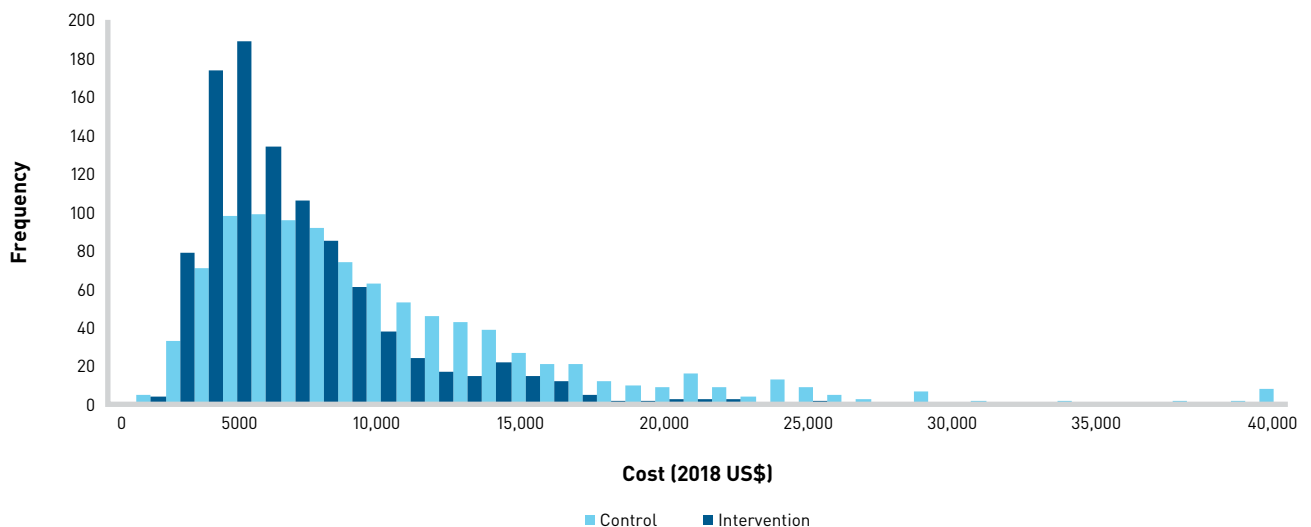
TABLE. Adjustment of Base-Case Values During Sensitivity Analyses of the Cost Benefit of the Pedometer-Mediated, Web-Based Intervention Among Veterans With COPD^{15,24,33,a}

Input	Parameter	Base case	SE/% change	Distribution	Notes
Adjusted relative risk attributable to intervention	<i>rrAEi</i>	0.52	0.22	Lognormal	Wan et al (2020) ²⁴
Probability of a COPD-related AE	<i>pAE</i>	0.59	0.04	β	Moy et al (2013) ¹⁵
Probability of hospitalization	<i>pHosp</i>	0.55	0.05	β	Moy et al (2013) ¹⁵
Rate of hospitalization	<i>rHosp</i>	1.75	1.75	Lognormal	Moy et al (2013) ¹⁵
Ratio of nonhospitalizations to hospitalizations	<i>raER</i>	1.27	1.27	Lognormal	Moy et al (2013) ¹⁵
Cost of Wi-Fi-enabled device	<i>cDevice</i>	\$200.00	$\pm 10\%$	Uniform	Estimated Wi-Fi-enabled smartphone cost (market value)
Cost of pedometer	<i>cPed</i>	\$35.00	$\pm 10\%$	Uniform	Estimated Omron pedometer cost (market value)
Cost of emergency visit with hospitalization	<i>cHosp</i>	\$13,367.79	\$2476.31	γ	MEPS 2018 ³³
Cost of emergency visit without hospitalization	<i>cER</i>	\$528.26	\$101.42	γ	MEPS 2018 ³³

AE, acute exacerbation; COPD, chronic obstructive pulmonary disease; MEPS, Medical Expenditure Panel Survey.

^aThe base case used assumed values or estimated mean values. SE was used to calculate γ distributions for probabilistic sensitivity analysis. β distributions for probabilistic sensitivity analysis were calculated using existing data from Moy et al (2013).¹⁵

FIGURE 2. Distribution of Monte Carlo Simulations With 1000 Iterations by Randomization Group



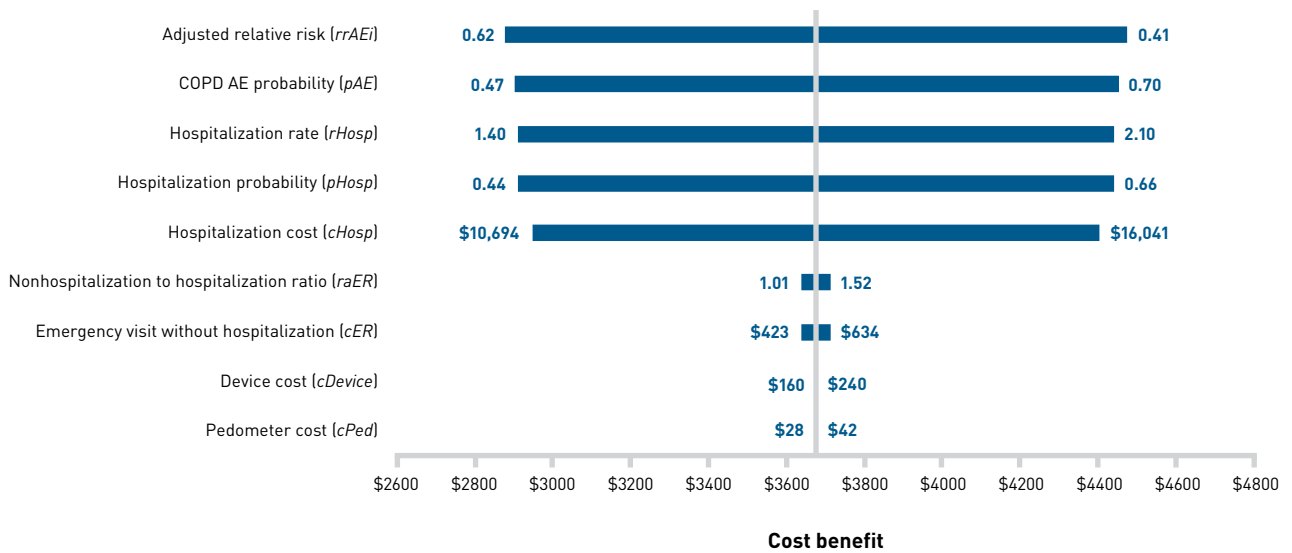
per participant in the control group. Using Monte Carlo simulation data (Figure 2), the mean attributable cost per participant who used the intervention was \$5465 (95% probability interval, \$5220-\$5709) compared with \$10,047 (95% probability interval, \$9612-\$10,481) for participants who used the pedometer alone, yielding a mean cost savings of \$4582 (95% probability interval, \$4084-\$5080). The mean attributable costs per participant for the intervention were significantly less than the mean attributable costs per participant in the control group ($P < .001$).

One-way sensitivity analysis was performed in which we varied each of the model inputs across a plausible range to evaluate the influence of each parameter on the findings. A tornado plot was created to visualize which of the parameters influenced cost the

most (Figure 3). Costs were most sensitive to the effect of the intervention on risk of experiencing a COPD-related acute exacerbation (21.7% of the swing in range of costs), the probability of experiencing a COPD-related acute exacerbation (20.4%), rate of hospitalization (19.9%), probability of hospitalization (19.9%), and cost of hospitalization (18.0%).

Because the clinical and economic impact of the intervention is most influenced by the adjusted relative risk attributable to intervention, we performed an additional post hoc sensitivity analysis to examine variation in cost savings per participant across varying degrees of intervention effectiveness. As the effect of the intervention on preventing COPD-related acute exacerbations increased, the cost savings attributable to the intervention increased (Figure 4).

FIGURE 3. Effects of Varying the Model Inputs on the Cost Benefit (control – intervention costs)^a



AE, acute exacerbation; COPD, chronic obstructive pulmonary disease.

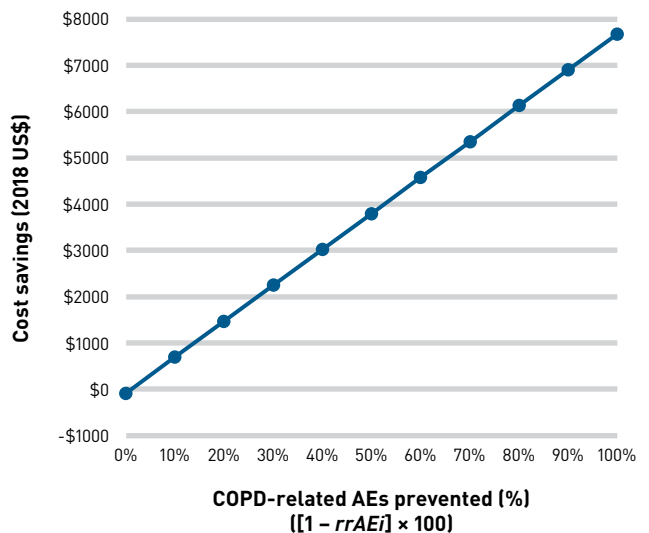
^aInput parameters were varied from the base case by 20% in each direction, except for hospitalization cost (*cHosp*) and emergency visit without hospitalization cost (*cER*), which were varied using ±1 SE from the base case.

Sensitivity analysis indicated that the intervention is cost neutral when it prevents 1.1% of COPD-related acute exacerbations.

DISCUSSION

The present study modeled intervention and health care utilization costs from a randomized controlled trial of a pedometer-based, web-mediated physical activity intervention in COPD.^{24,30} In this post hoc cost-benefit analysis, participants with COPD who were randomized to receive a pedometer-based, web-mediated intervention had substantially lower 1-year costs to the health care system compared with those who were randomized to a pedometer-alone control group. At the base case, the pedometer-based, web-mediated intervention was estimated to save \$3677 per participant compared with the pedometer-alone control. Sensitivity analyses of simulated iterations demonstrated a significant mean cost savings of \$4582 per participant compared with those in the control group. The effect modifier of the intervention on reduced risk of COPD-related acute exacerbations had the strongest effect on estimated cost savings of the intervention. Cost savings increased as the intervention became more effective in reducing risk of acute exacerbations, suggesting that highly effective interventions, such as the current web-based physical activity intervention, are likely to save costs. The present analysis estimated cost savings per participant. In 2014, there were 764,710 hospitalizations in nonfederal US hospitals with COPD as the primary diagnosis.³⁶ Avoiding even a fraction of costs incurred for emergency and inpatient COPD care would save hundreds of millions of health care dollars.

FIGURE 4. Sensitivity Analysis Results Across Variation in the Effectiveness of the Intervention on Preventing COPD-Related AEs



AE, acute exacerbation; COPD, chronic obstructive pulmonary disease; *rrAEi*, adjusted relative risk attributable to intervention.

To our knowledge, this is the first cost-benefit analysis of a technology-based physical activity intervention in COPD. Other cost analyses of in-person COPD self-management studies have shown cost savings related to the intervention groups,³⁷⁻³⁹ although they

were neither technology based nor focused specifically on physical activity. One study found that an in-person self-management program, augmented with a self-treatment component that focused on specifying an action plan for worsening COPD symptoms (ie, acute exacerbations), resulted in fewer exacerbations and saved €1078 per patient over 2 years compared with the self-management control group.³⁹

Economic analyses of interventions are critical for decision-making and potential implementation. A Cochrane review of technology-based interventions for self-management in COPD found a dearth of cost analyses and emphasized the importance of evaluating costs of such interventions.¹⁷ Indeed, one of the trials included in the Cochrane review was an earlier trial using the same pedometer-based, web-mediated intervention compared with a pedometer-alone group (Taking Healthy Steps^{18,20,27}). Before the present cost-benefit analysis, a cost-effectiveness analysis of the Taking Healthy Steps trial data demonstrated a benefit in quality-adjusted life-years (QALYs) in both the intervention and pedometer-alone control groups compared with usual care.³⁴ This earlier model used health-related quality-of-life data from the clinical trial (measured using the St George's Respiratory Questionnaire^{40,41}). Both the intervention group (\$12,947/QALY [95% uncertainty interval, \$4076-\$314,670]) and the pedometer-alone control group (\$9428/QALY [95% uncertainty interval, -\$565,577 to \$316,275]) were cost-effective in more than 75% of the probabilistic simulations with a willingness-to-pay threshold of \$50,000.³⁴ The present study extends this previous work to include downstream acute exacerbation-related health care utilization costs and compares the cost per participant between those who received the intervention and those who received only the pedometer. By comparing the pedometer-based, web-mediated intervention with the pedometer-alone control, we can evaluate the additional costs saved by using the website, over and above use of the pedometer. This is noteworthy because giving a participant a pedometer alone would conceivably be a less burdensome intervention than encouraging use of the website as well. However, there is little evidence to support that a pedometer alone is sufficient for long-lasting behavior change.⁴² Previous work has established that use of the website in conjunction with a pedometer effectively improves physical activity compared with use of a pedometer alone.^{20,30} The present cost-benefit analysis further supports that addition of the web-based component to the pedometer is cost-saving compared with a pedometer alone. In addition, the present study evaluates the costs saved per participant, as opposed to QALYs, providing a unique perspective that is in line with federal guidelines that discourage the use of QALYs as a threshold for decision-making regarding health services.⁴³

Acute exacerbations are important medical events in the natural history of COPD, adversely affecting morbidity, mortality, and disease-related costs.¹¹ Maintaining engagement in physical activity is an essential component of COPD management and acute exacerbation prevention.^{15,44,45} In-person health care visits and programs offer

opportunities to support COPD management and provide patient education on the importance of physical activity.¹⁰ Technology-based interventions are critical in overcoming the barriers many face accessing in-person care, which has been a particular problem during the COVID-19 pandemic. A recent study reported both significant increases in COPD acute exacerbations and reductions in physical activity during the pandemic.⁴⁶ Promisingly, a recent study reports that more than half of individuals with COPD started using technology-based health services during the pandemic, suggesting the potential for widespread reach of such technology-based interventions.⁴⁷ We assert that this technology-mediated physical activity intervention can overcome access-related barriers while contributing cost savings to the health care system.

Limitations

Development costs for the web-based intervention were not included because these have already been established and are sunk costs. Previous literature has estimated that the cost of development of a similar web-based intervention was approximately \$390,000 and included costs of website conceptualization, development, editing, and labor costs.⁴⁸ If we included costs attributable to website development, the intervention would be cost neutral when used in approximately 106 patients. Estimated health care utilization costs included both COPD-related inpatient and emergency medical and pharmacy costs³³; however, this analysis did not include other costs involved in care for acute exacerbations, such as outpatient medical costs (eg, home oxygen, over-the-counter medications). These expenditures likely embody only a small portion of the overall COPD-related costs; however, they may represent a considerable financial burden as out-of-pocket expenses to the individual living with COPD, who may be retired and/or disabled and living on a fixed income. In addition, personnel and data storage costs necessary for future implementation were not included. Finally, the primary trial and reduced risk of acute exacerbations were observed in a predominantly White, male veteran population and may not be generalizable to other populations.

CONCLUSIONS

This economic analysis of a randomized trial using a pedometer-based, web-mediated intervention to promote physical activity in patients with COPD found that the 1-year estimated cost to the health care system per participant is significantly lower for the intervention group compared with the control group. Despite increased upfront expenditures associated with the web-based intervention, decreased health care utilization from acute exacerbations in the intervention arm led to reduced aggregate costs. Increased physical activity significantly reduces risk of COPD acute exacerbations,^{15,24} which pose a major clinical and economic burden.⁴⁹ Clinicians and payers may be able to decrease the cost of COPD care through easily accessible, technology-based physical activity interventions. Clinical teams should consider use of technology-mediated interventions

to promote physical activity and reduce risk of acute exacerbations and related health care utilization among patients with COPD. ■

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