Feasibility of Wearable Physical Activity Monitors in Patients With Cancer

abstract

Purpose The feasibility of using physical activity monitors (PAMs) to measure functional status in patients with cancer is unclear. We aimed to determine the feasibility of using PAMs to longitudinally assess physical activity and performance status (PS) in patients with cancer.

Methods Patients with cancer who had Eastern Cooperative Oncology Group (ECOG) PS of 0 to 2 and were receiving systemic therapy were enrolled in a prospective pilot trial of PAM use. Feasibility was defined as patients using the PAM for > 50% of the observation period. We correlated PAM-reported measures with scores from ECOG PS and quality-of-life tools (Functional Assessment of Cancer Therapy–General [FACT-G], Quick Inventory of Depressive Symptoms–Self-Rated 16 [QIDS-SR16], and Brief Fatigue Inventory [BFI]) using Pearson's correlation test. Patients were surveyed regarding their experience with PAMs at study completion.

Results In all, 24 patients were enrolled; mean age was 54 years, 16 (67%) were women, and 19 (79%) were white. Twenty-three patients (96%) met the primary end point of feasibility. The median duration of follow-up was 69 days. Mean PAM-measured steps for ECOG PS of 0, 1, and 2 were 5,911, 1,890, and 845 steps per day, respectively ($P = .002$). Minimum steps per day correlated with BFI ($r = -0.53$; $P < .01$), FACT-G ($r = 0.45$; $P = .02$), and QIDS-SR16 ($r = -0.57$; $P < .01$). Eighteen patients (75%) reported a positive experience with the PAM.

Conclusion PAMs are a feasible tool for measuring long-term physical activity in patients with cancer who are receiving systemic therapy. PAM-derived measures correlated with clinician-assessed PS.

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INTRODUCTION

An oncologist's evaluation of a patient's functional status is a critical assessment made during a clinical encounter. This assessment can influence decisions regarding cancer therapy and eligibility for clinical trials, and it can be used to track progress throughout therapy.¹⁻³ The level of physical activity is also an important predictor of outcomes, and patients with poor performance status (PS) who receive chemotherapy have poorer survival, reduced response rates, and worse quality of life (QOL).⁴ Functional status has historically been recorded via clinical judgment and patient questionnaires such as Karnofsky performance status and Eastern Cooperative Oncology Group (ECOG) PS. Health-related QOL measures such as the Functional Assessment of Cancer Therapy (FACT) score are also used to determine well-being.⁵ These assessments are subjective and are prone to interobserver differences and bias, which can be especially relevant for elderly patients in whom subtle differences in activity can carry more clinical significance.

New technology, particularly wearable physical activity monitors (PAMs), allow longitudinal assessment of functional status in patients' normal daily activities with a high correlation to gold-standard techniques.⁶ PAMs allow for an unprecedented assessment of functional status outside the formal clinical setting.⁷ The utility of PAMs to assess functional status in patients with chronic diseases, such as diabetes mellitus, congestive heart failure, and chronic obstructive pulmonary disease (COPD) has been studied.⁸⁻¹⁰ Patients with cancer tend to be older, more frail, and less technologically literate.¹¹⁻¹⁴ There are limited data evaluating newer generation devices in oncology populations, and studies have been limited by including only patients who have a single type of cancer, by short follow-up duration (1 to 3 weeks), and by lack of comparisons between PAM-derived step counts and ECOG PS.^{15,16} We aimed to determine the long-term feasibility of PAMs to longitudinally assess physical activity and PS in patients with cancer who were receiving therapy.

METHODS

This was a pilot study to assess the feasibility of using a commercially available wearable PAM, the Fitbit Flex, in adult patients with cancer receiving systemic therapy. Secondary objectives were to measure PAM-derived physical activity (ie, number of steps, minutes of activity, degree of activity, and sleep [minutes of sleep]) and to correlate PAM-derived measures with clinician-assessed ECOG PS and QOL tools, including the Functional Assessment of Cancer Therapy–General (FACT-G), Quick Inventory of Depressive Symptoms–Self-Rated 16 (QIDS-SR16), Pittsburgh Sleep Quality Index (PSQI), and Brief Fatigue Inventory (BFI).^{17–20} We used the Fitbit Flex for this study because it can easily link to the Fitabase database and because we intended to capture only markers of physical activity but not other markers such as posture or heart rate. The Fitbit Flex fit into our budget and was sleek and convenient for wearing on the wrist. The Fitbit has been compared with other objective tools to measure physical activity and has been shown to have excellent external validity.²¹

The primary end point of the study was the feasibility of using a PAM. Days with more than zero recorded steps were counted as “PAM used,” and days with zero recorded steps were considered “PAM not used.” The rate of device use was defined as the proportion of PAM used days divided by days on study. Feasibility was defined as patients who used their PAM for > 50% of their observation period (12 weeks). Patients’ experience with wearable PAMs was assessed by using a post-study survey (Appendix Fig A1). A positive experience with PAM use was defined as a satisfaction level of 4 or 5 overall on a scale of 5. Eligible patients were approached by a research study coordinator or referred by their health care provider for screening in the outpatient oncology clinic at the Harold Simmons Cancer Center of the University of Texas Southwestern Medical Center, a National Cancer Institute–designated Comprehensive Cancer Center. Inclusion criteria were age $\geq$ 18 years, receiving or planning to receive outpatient therapy for cancer, having a baseline ECOG PS of 0 to 2, being an English speaker, and having access to a smartphone that could be synchronized with the PAM. The following are exclusion criteria: recent injury, which could impair mobility; major

surgery within 4 weeks; inability to comply with study requirements as determined by the investigator; medical or psychiatric condition which, in the investigator’s opinion, would affect the successful completion of study; and the use of a personal PAM in the last 6 months.

After obtaining informed consent, patients were provided with a wearable PAM. Research staff helped patients set up the commercial mobile phone–based application on the patient’s personal smartphone with individual log-in information. Patients were asked to wear the device continuously, except while bathing. Commercially available marketing material was provided as an introduction to the device, which included instructions on charging and syncing. The device was returned to the study team at the conclusion of the study.

Patients were asked to complete functional and QOL surveys at the time of enrollment, once every 4 weeks, and at the end of study period. Four questionnaires were obtained by a research coordinator at a standard-of-care visit to the clinic. FACT-G is a 27-item scale designed to measure multidimensional QOL in patients with cancer.²⁰ The QIDS-SR16 is a 16-item version of the 30-item Inventory of Depressive Symptoms designed to assess severity of depression-specific symptoms.¹⁷ The PSQI is a 19-item scale designed to assess sleep quality and disturbances.¹⁸ The BFI is a 9-item scale designed to assess fatigue in patients with cancer.¹⁹

Clinician-assessed ECOG PS was obtained by reviewing electronic medical records. Patients completed a post-study questionnaire (Appendix Fig A1) to rate their experience using the PAM on a Likert scale of 1 to 5 (1, very poor; 5, very good).

An online research platform (www.fitabase.com) was used to aggregate data from all study devices for analysis. PAM-derived data were downloaded at the end of the study period. The study was approved by the University of Texas Southwestern Medical Center Institutional Review Board, and written informed consent was obtained from each participant.

Statistical Analysis

Descriptive statistics were reported for patient variables such as age, sex, ethnicity, type of cancer, and ECOG PS. PAM-derived variables included number of steps (minimum, maximum, and

Fig 1. CONSORT diagram for this feasibility pilot trial.

median), minutes of sleep, and sedentary time. An exact binomial method was used to calculate the 95% CIs. Composite score of functional and QOL questionnaires was calculated according to published methods.¹⁷⁻²⁰ PAM-derived number of steps was correlated with ECOG PS and scores on QOL questionnaires by using Pearson's correlation test with SPSS v24 (SPSS, Chicago, IL).

RESULTS

Study Participants

The CONSORT diagram for this trial is presented in [Figure 1](#).²² We assessed 52 patients for eligibility and enrolled 27 into the study. Of these 27, three patients were excluded from the final analysis (two withdrew consent and one died [we did not have data for these three patients]). For the 24 patients analyzed, the mean age was 54 years. Among the 24 patients, 16 (67%) were women and 19 (79%) were white. The most common primary site of malignancy was the GI tract (13 [48%]). Clinician-assessed ECOG PS was 0 for 13 patients (54%), 1 for nine patients (38%), and 2 for two patients (8%). [Table 1](#) provides a summary of baseline characteristics of the study participants.

Feasibility and Functional Capacity Assessment

[Figure 2](#) shows PAM use by total days on study and by days used for each patient by ECOG PS

0, 1, and 2. Of the 24 patients with available data, 23 (96%) adhered to wearing the PAM for > 50% of the observation period. Nineteen patients (79%) adhered to wearing the PAM for > 70% of the observation period. The follow-up observation period ranged from 4 to 112 days (median, 69 days). [Figure 3](#) demonstrates the drop-off rates for PAM use; initially, PAM use was consistent (90% using at 4 weeks), with a steady drop-off rate as time passed (50% using at 10 weeks).

The median step count was 3,447 steps per day (interquartile range, 1,419 to 6,334 steps per day). The median sedentary minutes per day was 935. No statistically significant difference in number of steps, activity, or duration of sleep was seen among sex and ethnic groups. Patient's age significantly correlated with minimum number of steps per day ($r = -0.633$; $P < .001$). The post-study questionnaire revealed that 18 patients (75%) rated their experience of using the PAM as ≥ 4 on a Likert scale of 1 to 5 (1, very poor; 5, very good).

Physical Activity and QOL

The results of patient-reported outcomes and correlations are summarized in [Table 2](#). The median number of steps significantly differed by clinically assessed ECOG PS ($P = .002$). Patients

Table 1. Baseline Patient Characteristics

Characteristic	No.	%
Total No. of patients	24	
Mean age, years $\pm$ SD	54 $\pm$ 12.5	
Female sex	16	67
Ethnicity		
White	19	79
African American	4	17
Asian	1	4
Primary disease site		
GI	12	50
Breast	4	17
Lung	3	13
Other	5	21
ECOG performance status		
0	13	54
1	9	38
2	2	8

Abbreviations: ECOG, Eastern Cooperative Oncology Group; SD, standard deviation.

Fig 2. Physical activity monitor use by total days on study and days physical activity monitor was used for each patient by Eastern Cooperative Oncology Group (ECOG) performance status 0, 1, and 2.

with ECOG PS of 0 had a median of 5,911 steps per day; ECOG PS of 1, 1,890 steps per day; and ECOG PS of 2, 845 steps per day. The minimum number of steps per day correlated significantly with FACT-G ($r = 0.425$; $P = .021$), QIDS-SR16 ($r = -5.66$; $P = .003$), and BFI ($r = -0.533$; $P = .006$). No correlation was seen between PAM measures and PSQI. Median and mean steps per day correlated with ECOG PS of 0 versus 1 versus 2 ($P < .001$), whereas minimum and maximum steps per day did not ($P = .71$).

DISCUSSION

In this prospective study, we demonstrate that PAMs are a feasible tool for assessing long-term physical activity in patients with cancer who are undergoing therapy. PAM-derived data also accurately correlated with clinician assessments and QOL measures using standardized tools. The number of steps per day separated patients with different clinician-assessed ECOG PS with extreme sensitivity and also correlated

with multiple functional and QOL tools such as FACT-G, QIDS-SR16, and BFI.

In this study, we showed that PAM devices allow monitoring for extended durations of time and with relatively automated data capture. Our data suggest that longitudinal data collection may expand the clinical relevance of physical activity data. This study provides insight into the anticipated attrition in use of wearable PAMs in patients with cancer. In this study, patients adhered to the PAMs for an extended period of time despite actively receiving cancer therapy while on study, and only two patients withdrew consent.

PAM-derived measures were able to differentiate between clinician-assessed PS, with significant differences in steps noted between patients with ECOG 0 compared with those who had an ECOG PS of 1 or 2. This is an important first step in understanding the relevance of PAMs in the clinic. The longitudinal collection of data provides an opportunity to improve selection of patients for treatment and identify subtle changes in PS over time. The ability to identify early departures from baseline may be the first step toward recognizing clinical decline in patients, may offer a window for intervention to prevent potential treatment-related toxicity, and may reduce emergency room visits or hospitalization. The number of patients with an ECOG PS of 2 was limited ($n = 2$), and both were barely able to use the device for time on study < 30 days (Fig 2). Patients with an ECOG PS of 0 or 1 had more consistent patterns of use. Although patients with an ECOG PS of 0 or 1 spent a similar amount of time on study and used the device a similar proportion of time, their actual recorded activities were very different. Patients with ECOG

Fig 3. Drop-off curve for physical activity monitor use.

Table 2. Correlation Between PAM-Derived Variables and Functional and QOL Measures

Measure	Mean No. of Minutes of Sleep Duration	Mean No. of Steps per Day	Median No. of Steps per Day	Minimum No. of Steps per Day	P
FACT-G	0.283	0.199	0.205	0.452	< .05
QIDS-SR16	0.062	−0.121	−0.1	−0.566	< .05
PSQI	−0.126	−0.111	−0.121	−0.094	
BFI	−0.114	−0.212	−0.222	−0.533	< .05

NOTE. Data are Pearson correlation coefficients.
Abbreviations: BFI, Brief Fatigue Inventory; FACT-G, Functional Assessment of Cancer Therapy–General; PAM, physical activity monitor; PSQI, Pittsburgh Sleep Quality Index; QIDS-SR16, Quick Inventory of Depressive Symptoms–Self-Rated 16.

PS 0 had a median of 5,911 steps per day, ECOG PS 1 had 1,890 steps per day, and ECOG PS 2 had 845 steps per day. This might be a sensitive method for differentiating PS: patients with an ECOG PS of 0 used the device and had a good step count, patients with an ECOG PS of 1 used the device but had one third of the step count, and patients with an ECOG PS of 2 did not use the device beyond 4 weeks and had < 1,000 steps per day. Traditional measures of assessing patient functional status such as ECOG PS and Karnofsky performance status are marred by poor interobserver agreement, especially in differentiating narrow differences in performance between ECOG PS 0 and 1.²³ These scales have low associations with QOL and symptom measures.²⁴

Clinician-assessed and patient-assessed activity levels are also prone to bias. In one study, patients with cancer who were undergoing chemotherapy self-reported 366% higher levels of physical activity compared with objective measures.²⁵ In our study, the median step count was 3,447 steps per day. Patients with ECOG PS of 0 had a median of 5,911 steps per day, those with an ECOG PS of 1 had 1,890 steps per day, and those with an ECOG PS of 2 had 845 steps per day. Studies in healthy US adults have demonstrated daily step counts of approximately 5,000 to 7,000 per day.^{26,27} Thus, patients with an ECOG PS of 0 had activity levels similar to those of healthy adults. There was a sharp decrease in number of steps per day going from an ECOG PS of 1 to an ECOG PS of 2. Studies in patients with congestive heart failure and COPD have demonstrated step counts per day of approximately 5,500 to 6,000^{28,29} and showed a reduction with advancing stage of Global Initiative for

Chronic Obstructive Lung Disease (GOLD stage). In one study, patients with GOLD stage 1 COPD averaged 5,856 steps per day, which showed a consistent decline as the GOLD stage advanced; patients with GOLD stage 4 averaged 3,707 steps per day ($P = .0046$).²⁸ A majority of patients in our study were women; a large-scale study reported that women in the United Kingdom take 4,908 steps per day on average, whereas men take 5,982 steps per day.³⁰ Although there are aesthetic differences in some PAMs for men versus those for women, inherent differences in activity may explain some observed differences in step count per day in men versus women. Sensitivity of PAMs for men and women undergoing the same activity has not been formally studied but is unlikely to be different. Sex did not show any correlation with PAM-derived measures in our study.

The effect of cancer and cancer treatments on PS can be modest initially, and departures from a patient’s baseline can herald longer-term toxicity and risk of complications. It is possible to recognize these changes through collection and analysis of data over an extended period of time. Previous research-grade monitors did not allow extended, longitudinal monitoring.^{15,16} This study has demonstrated the feasibility of measuring patient activity for many months, with a high proportion of patients remaining on observation for more than 6 weeks. Post-study questionnaires reflected that 75% of patients regarded their experience with PAM as “good” or “very good.” Moreover, patients felt that they were motivated to stay active while wearing the PAM and had no issues with using the device.

There has been a spotlight on patient-reported outcomes over the last decade. Electronic patient-reported symptoms using a Web-based tool can improve patient QOL, reduce emergency room visits, and remarkably improve overall survival.³¹ This single-center experience supports the effect of longitudinal patient-reported symptom monitoring on patient outcomes in clinical practice. The success in using electronic Web-based symptom reporting in clinical practice has contributed to the development of a National Cancer Institute (NCI) Patient-Reported Outcomes (PRO) Version of the Common Terminology Criteria for Adverse Events (PRO-CTCAE). PRO-CTCAE is being developed as a tool to bridge the strength of PRO tools with validated

toxicity assessment measures (eg, NCI-CTCAE) on which current clinical trials rely.³² This tool uses self-reported PRO-CTCAE items that are captured via wireless devices and can measure adverse events at multiple time points. Validation is still needed for the PRO-CTCAE tools that formally assess the impact of treatment toxicity on clinical trial outcomes (eg, decisions regarding dose-limiting toxicities). These electronic Web-based PRO tools are a decade old, are still vulnerable to recall bias, and are designed to assess symptoms only for the prior 7 days. Wearable PAMs can objectively and semiautonomously report longitudinal data to a central data repository for grading and assessment and can overcome many of these issues. Previous studies evaluating PAMs in patients with cancer focused only on patients with lung and prostate cancer, and assessed only short-term use (< 3 weeks).^{15,16} Data regarding correlations with clinician-assessed PS and physical activity are lacking.

In this study, individual PAMs were provided to patients and registered to their personal mobile devices. The investigators used a Web-based research platform (Fitabase) to aggregate data, which were downloaded for analysis. There were no reminders provided to patients which, if systematically implemented, could increase compliance after the initial setup. Having a smartphone was a requirement for this study because the memory capacity of the Fitbit Flex is 1 week, and not all patients were required to visit the health system every week. We did not instruct patients to come to the clinic just for syncing data. As technology improves and memory capacities of these devices increases, this requirement might be less limiting. In our study, six patients were excluded because they did not have a smartphone. We did not assess the effect of PAMs on modifying physical activity. The most common reasons for refusal to

participate were the patient's perceived inability to manage the PAM, including charging or syncing to their smartphones, and their unwillingness to commit to study procedures. This study used a convenience sampling method for enrollment and allowed only patients with access to a smartphone. Improving technology of wearable PAMs will simplify the process of syncing and charging devices and potentially broaden the acceptability of their use. We classified patients as having used the PAM for the day if they used the PAM for any portion of the day. Use was captured if the PAM detected any steps during the calendar day. Unfortunately, formal durations and time of use per day were not available. Previous studies in patients with cancer have shown that the initial burst of PAM use decreases after 4 weeks of using the wearable device.³³ Therefore, we elected to have an extended observation period in this study. We did not include a formal run-in period in this study, but future studies could consider doing this because the initial burst of enthusiasm could taper off once patients become familiar with the technology. Future studies that focus on specific interventions for measuring physical activity could also consider a control arm. Follow-up studies could enroll a larger sample size for each ECOG PS and study the duration of PAM use required to detect an ECOG PS change, to analyze whether these data can be used for preclinical detection of impact and intervention, or just as a retrospective tool.

This study represents the first step in validating wearable newer-generation PAMs for use in clinical trials. The high consent rate among referred patients and low attrition rate and positive user experience further supports the feasibility of PAMs in this patient population.

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REFERENCES

1. Dimeo FC, Stieglitz RD, Novelli-Fischer U, et al: Effects of physical activity on the fatigue and psychologic status of cancer patients during chemotherapy. *Cancer* 85:2273-2277, 1999
2. Mishra SI, Scherer RW, Snyder C, et al: The effectiveness of exercise interventions for improving health-related quality of life from diagnosis through active cancer treatment. *Oncol Nurs Forum* 42:E33-E53, 2015
3. Fong DY, Ho JW, Hui BP, et al: Physical activity for cancer survivors: Meta-analysis of randomised controlled trials. *BMJ* 344:e70, 2012
4. Schnipper LE, Smith TJ, Raghavan D, et al: American Society of Clinical Oncology identifies five key opportunities to improve care and reduce costs: The top five list for oncology. *J Clin Oncol* 30:1715-1724, 2012
5. Garman KS, Cohen HJ: Functional status and the elderly cancer patient. *Crit Rev Oncol Hematol* 43:191-208, 2002
6. Papi E, Osei-Kuffour D, Chen YM, et al: Use of wearable technology for performance assessment: A validation study. *Med Eng Phys* 37:698-704, 2015
7. Beg MS, Gupta A, Stewart T, et al: Promise of wearable physical activity monitors in oncology practice. *J Oncol Pract* 13:82-89, 2017
8. Vaes AW, Cheung A, Atakhorrami M, et al: Effect of 'activity monitor-based' counseling on physical activity and health-related outcomes in patients with chronic diseases: A systematic review and meta-analysis. *Ann Med* 45:397-412, 2013
9. Kawagoshi A, Kiyokawa N, Sugawara K, et al: Effects of low-intensity exercise and home-based pulmonary rehabilitation with pedometer feedback on physical activity in elderly patients with chronic obstructive pulmonary disease. *Respir Med* 109:364-371, 2015
10. Vallance JK, Courneya KS, Plotnikoff RC, et al: Randomized controlled trial of the effects of print materials and step pedometers on physical activity and quality of life in breast cancer survivors. *J Clin Oncol* 25:2352-2359, 2007

11. Fox BI, Felkey BG: Identifying and addressing technology challenges among older adults. *Hosp Pharm* 49:780-781, 2014
12. Goel MS, Brown TL, Williams A, et al: Disparities in enrollment and use of an electronic patient portal. *J Gen Intern Med* 26:1112-1116, 2011
13. Handforth C, Clegg A, Young C, et al: The prevalence and outcomes of frailty in older cancer patients: A systematic review. *Ann Oncol* 26:1091-1101, 2015
14. Berger NA, Savvides P, Koroukian SM, et al: Cancer in the elderly. *Trans Am Clin Climatol Assoc* 117:147-155, 2006
15. Bade BC, Brooks MC, Nietert SB, et al: Assessing the correlation between physical activity and quality of life in advanced lung cancer. *Integr Cancer Ther* [10.1177/1534735416684016](https://doi.org/10.1177/1534735416684016) [epub ahead of print on December 1, 2016]
16. Rosenberg D, Kadokura EA, Bouldin ED, et al: Acceptability of Fitbit for physical activity tracking within clinical care among men with prostate cancer. *AMIA Annu Symp Proc* 2016:1050-1059, 2017
17. Rush AJ, Trivedi MH, Ibrahim HM, et al: The 16-Item Quick Inventory of Depressive Symptomatology (QIDS), clinician rating (QIDS-C), and self-report (QIDS-SR): A psychometric evaluation in patients with chronic major depression. *Biol Psychiatry* 54:573-583, 2003
18. Buysse DJ, Reynolds CF III, Monk TH, et al: The Pittsburgh Sleep Quality Index: A new instrument for psychiatric practice and research. *Psychiatry Res* 28:193-213, 1989
19. Mendoza TR, Wang XS, Cleeland CS, et al: The rapid assessment of fatigue severity in cancer patients: Use of the Brief Fatigue Inventory. *Cancer* 85:1186-1196, 1999
20. Cella DF, Tulsky DS, Gray G, et al: The Functional Assessment of Cancer Therapy scale: Development and validation of the general measure. *J Clin Oncol* 11:570-579, 1993
21. Evenson KR, Goto MM, Furberg RD: Systematic review of the validity and reliability of consumer-wearable activity trackers. *Int J Behav Nutr Phys Act* 12:159, 2015
22. Moher D, Schulz KF, Altman DG: The CONSORT statement: Revised recommendations for improving the quality of reports of parallel-group randomised trials. *Lancet* 357:1191-1194, 2001
23. Sørensen JB, Klee M, Palshof T, et al: Performance status assessment in cancer patients: An inter-observer variability study. *Br J Cancer* 67:773-775, 1993
24. Suh SY, Leblanc TW, Shelby RA, et al: Longitudinal patient-reported performance status assessment in the cancer clinic is feasible and prognostic. *J Oncol Pract* 7:374-381, 2011
25. Vassbakk-Brovold K, Kersten C, Fegran L, et al: Cancer patients participating in a lifestyle intervention during chemotherapy greatly over-report their physical activity level: A validation study. *BMC Sports Sci Med Rehabil* 8:10, 2016
26. Bassett DR Jr, Wyatt HR, Thompson H, et al: Pedometer-measured physical activity and health behaviors in U.S. adults. *Med Sci Sports Exerc* 42:1819-1825, 2010
27. Berko J, Goetzel RZ, Roemer EC, et al: Results From the Bipartisan Policy Center's CEO Council Physical Activity Challenge to American Business. *J Occup Environ Med* 58:1239-1244, 2016
28. Moy ML, Danilack VA, Weston NA, et al: Daily step counts in a US cohort with COPD. *Respir Med* 106:962-969, 2012
29. Thorup C, Hansen J, Grønkjær M, et al: Cardiac patients' walking activity determined by a step counter in cardiac telerehabilitation: Data from the intervention arm of a randomized controlled trial. *J Med Internet Res* 18:e69, 2016
30. Althoff T, Sosič R, Hicks JL, et al: Large-scale physical activity data reveal worldwide activity inequality. *Nature* 547:336-339, 2017
31. Basch E, Deal AM, Dueck AC, et al: Overall survival results of a trial assessing patient-reported outcomes for symptom monitoring during routine cancer treatment. *JAMA* 318:197-198, 2017

32. Basch E, Pugh SL, Dueck AC, et al: Feasibility of patient reporting of symptomatic adverse events via the Patient-Reported Outcomes Version of the Common Terminology Criteria for Adverse Events (PRO-CTCAE) in a chemoradiotherapy cooperative group multicenter clinical trial. *Int J Radiat Oncol Biol Phys* 98:409-418, 2017
33. Backman M, Wengström Y, Johansson B, et al: A randomized pilot study with daily walking during adjuvant chemotherapy for patients with breast and colorectal cancer. *Acta Oncol* 53:510-520, 2014

Appendix

Fitbit Feedback Questionnaire

1. Overall, how would you rate your experience wearing the Fitbit device?
1 2 3 4 5
Very Poor Very Good
2. How many days did you wear the device during the week?
1 2 3 4 5 6 7
3. If you wore the device for less than 7 days last week, what were the reasons for not wearing the device? (Choose all that apply)
 - ☐ Forgot to put the device on
 - ☐ Forgot to charge the device
 - ☐ Don't like wearing the device
 - ☐ Lost/misplaced the device
 - ☐ Other: _____
 - ☐ N/A
4. Please rate your experience charging the device.
1 2 3 4 5
Very Poor Very Good
5. Please rate your experience viewing your activity level on the device.
1 2 3 4 5
Very Poor Very Good
6. Please rate your experience using the Fitbit app on your phone.
1 2 3 4 5
Very Poor Very Good
7. How often did you use the Fitbit app on your phone?
 - ☐ Never
 - ☐ Once per week
 - ☐ Every 2 to 3 days
 - ☐ Once per day
 - ☐ Multiple times per day
8. Please share any other feedback you have regarding your experience wearing the Fitbit device.

Fig A1. End-of-study patient survey.