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Research Article

Development of A Tailored Home-Based Exercise Program for Low-Income Cancer Survivors with Multiple Chronic Conditions: A Pilot Study

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Abstract

Background: The established benefits of physical activity for managing chronic illnesses underscore the importance of addressing this in low-income cancer survivors with Multiple Chronic Conditions (MCC). However, increasing physical activity in this population presents challenges. This paper reports on the initial phase of a clinical trial (clinical.gov: NCT3874754) evaluating the feasibility of a home-based exercise program, employing mobile technologies and tailored exercises for this population. **Methods:** Conducted as an open-label one-group pre-post test pilot study, the intervention involved four home visits, daily use of a physical activity tracker, and a phone application over four weeks. Cancer survivors with at least one additional chronic condition and annual incomes below $50,000, were assessed for program feasibility through recruitment and retention rates, implementation duration, compliance, adverse events, and participant perceptions. Questionnaires measured well-being, symptoms, and resilience at baseline (week 1) and program completion (week 4). Descriptive statistics analyzed the data. **Results:** Nine participants were recruited, with a 78% retention rate and 71% adherence to weekly exercise goals and daily surveys. Physical activity tracking device compliance was satisfactory, and no adverse events were reported. Quantitative analysis revealed a 7-40% increase in weekly average steps for most participants. Participants reported reduced pain (6%) and fatigue (7%), with improved resilience (11%) and well-being in both physical (8%) and mental components (2%). **Conclusion:** The study supports the feasibility of the program. While acknowledging the small sample size, the findings demonstrate promising impacts on physical activity and symptom management, warranting further exploration with potential adjustments.

Trial Registration: ClinicalTrial.gov number is NCT03874754, last updated on 24/08/2020

Keywords: Cancer survivors; Multiple chronic conditions; Low-incomes; Exercise; Mobile technology

Background

More than 12 million Americans are cancer survivors living with one or more comorbid chronic conditions (e.g., type 2 diabetes, cardiovascular diseases) [1]. Compared with cancer survivors without chronic conditions, cancer survivors with Multiple Chronic Conditions (MCC) have a significantly higher prevalence and severity of symptoms [2-6]. Resilience, an ability to resist, recover, or rebound from stressors, [7] influences the perception of symptoms including fatigue and depression [8-13]. People with high resilience report lower depression, fatigue, and better physical functioning than those with low resilience [7,14-16]. MCC-related symptoms affect individuals' functional capacity, quality of life, and a higher risk of premature death than those without symptoms [17,18]. Active participation by persons is paramount in the effective management of MCC-related symptoms, which are long-term, variable, and often degenerative. Low-income persons are more likely to not adhere to the disease and symptoms management recommendations due to financial limitations and lack of accessibility to the facility [19]. As such, self-management intervention programs that provide persons and their families with information and skills that enhance their ability to participate in their health care (e.g., symptom management, treatment adherence) and that consider individual context and goals are increasingly recognized not only as an essential component of chronic illness management but also as part of secondary prevention and a way of reducing the burden of chronic illness on individuals and the community.

Increasing Physical Activity (PA) is one of the most effective interventions for managing chronic conditions and symptoms, and for improving one's health [20]. Studies have shown that a continuous aerobic moderate-intensity exercise program not only reduces fatigue, pain, [21,22] and improves AWB, [23,24], but also delays the onset and progression of other chronic conditions. In spite of the benefits of PA, evidence shows that less than 10-20% of patients with chronic conditions are active [25-28]. To overcome the barriers to exercise, home-based exercise programs have been developed and report promising effectiveness on pain, fatigue, and AWB of cancer survivors with several chronic conditions [29-31]. However, these studies have examined the effectiveness of the programs on an individual chronic condition and reported that most home-based exercise programs are challenged by a lack of motivation and low engagement rates with the exercise regimen [32-34].

Recent evidence shows that the use of technology to provide immediate feedback on physical performance and reminder messaging can increase motivation and adherence to PA [34-36]. The scientific premise of this messaging is based on the self-efficacy theory. The performance accomplishments and feedback can impact the self-efficacy that leads to the motivation to maintain healthy behaviors [35]. A recent review paper reported that self-monitoring and performance feedback are key components of successful mobile health interventions to promote physical activity in older cancer survivors [37]. To address the limitations of engagement in exercise interventions, a home-based exercise (iHBE) program that integrated a smartphone application and physical activity tracking technology with a goal-setting and problem-solving intervention to tailor PA to individual daily life and physical fitness goals and preferences seems to provide promising results [38-40].

In the past decade, there has been a significant increase in digitally delivered exercise programs targeting individuals with various chronic conditions (e.g., cardiovascular diseases, osteoarthritis, cancer, and chronic kidney disease). However, the majority are focused on individuals with a single chronic condition and target achieving recommended daily physical activity goals and often do not include individuals' incomes as one of the factors. Exercise programs for low-income cancer survivors with MCC may require unique consideration of an individual's financial burdens and challenges (e.g., multiple caregiving demands, and less access to safe and clean spaces to exercise due to unsafe living conditions, etc.) [41,42]. While integrating mobile and physical activity tracking technologies seems to have a positive impact on individuals' physical activity levels, evidence on the feasibility and challenges of these devices and physical activity among low-income individuals was limited. Our pilot study aims to develop a tailored program that could meet the complex needs of cancer survivors with at least one or more comorbidities who have annual incomes of less than 50,000 US dollars (less than 200% above the US 2019 national poverty line), using the goal setting process and tailored the exercise recommendation weekly to meet individual's physical function and challenges.

The aim of this paper is to assess the feasibility of the home-based exercise program using mobile technologies (physical activity tracker and phone application) and tailored exercise for low-income cancer survivors with MCC.

Methods

Aims

The purposes of this study were as follows: (1) to develop and test the feasibility of a home exercise program tailored to participants' goals and preferences among low-income cancer survivors with MCC, and (2) to pilot test the effect of the program on symptoms (pain and fatigue), resilience and well-being.

Study Design

This study was an open-label pre-post test pilot study to examine the feasibility of an exercise intervention, mobile technology, and data collection process of the iHBE program in cancer survivors with MCC and pain problems.

Sample and Setting

Inclusion criteria included the following: adults aged 55 and older, diagnosed with cancer and at least one more chronic condition (e.g., diabetes, hypertension, etc.) for at least a year, self-reported annual income below 50,000 US dollars (below 200% of the federal poverty level) [25], and experiencing at least mild pain and fatigue (self-reported of at least 3 on the scale 0 (no symptom) to 10 (worst possible symptom). Exclusion criteria included: undergoing cancer treatment, having an active infection (e.g., fever, localized redness, swelling, sinus congestion), or being diagnosed with a psychological disorder (e.g., suicidal ideation, extreme anxiety, or depression).

Recruitment and Data Collection

Upon receiving approval from the Johns Hopkins University Institutional Review Board, participants were recruited from home healthcare agencies in Baltimore, Maryland using flyers, in-person contact, and referrals from home health providers. After participants were screened for eligibility criteria and signed the informed consent, a research team member visited the home for the initial assessment and to provide instruction on the physical activity tracking device (Fitbit, San Francisco, CA), to download and set up the two smartphone applications; one for sending and receiving a daily symptoms survey and another for activity tracking device assess the participants' baseline physical capacity, and determine their physical activity goals and preferences. Participants were asked to wear the physical activity tracker on the non-dominant arm 24 hours/day and respond to a short symptoms survey on the smartphone application daily for 4 weeks. For participants who did not have a smartphone, a research phone was lent. Participants received a hard copy of the questionnaires and were asked to complete the questionnaires for outcomes at baseline (T1) and completion (T2). At the end of the program, participants were asked to complete open-ended questions to evaluate the program. The completed questionnaires were collected during the home visits. At the end of the program, each participant received 40 US dollars cash for participating in the study.

Intervention

The initial 4-week tailored technology-enhanced home-based exercise (iHBE) program was developed by the following research team: a symptom management expert (NL), an American College of Sports Medicine certified physiologist (DM), and an oncologist (JYS). The program was developed based on existing evidence to address the challenges in most exercise programs (Figure 1). The combination of the tailored home exercise intervention based on the goals, preferences, and baseline physical function, and mobile technologies (e.g., physical activity tracker and smartphone application) to monitor physical activity and symptoms, and adherence to a home exercise program. Prior to the data collection, the research staff was trained on 1) setting up the physical activity tracking device and smartphone application and how to extract and interpret the daily symptoms and step data; 2) troubleshooting some technical issues for the physical activity tracking device and the smartphone application; 3) communication with the participants on goals setting and adjusting weekly exercise goals and 4) exercise safety.

We conducted a baseline home visit (week 0) to set up and train participants on how to use the physical activity tracking device and smartphone applications. Participants were asked to wear the physical activity tracker and respond to the daily symptoms survey for one week for baseline physical activity (step count and active minutes) and asked to select one of the following exercise modalities: National Institute on Aging Go4Life exercise, walking, modified Otago exercise, or yoga. The physical activity goals were set up with the participants based on their selected exercise options and baseline physical activity levels. On weeks 1 to 3, a research staff member conducted weekly home visits to review each participant's weekly performance (activity and sleep) from the physical activity tracker and daily symptoms from daily symptoms survey through the smartphone application, discuss the achievement of goals and challenges of exercising at home, and to adjust the physical activity goals.

Participants were trained for 15-20 minutes for exercise based on their selected modalities. The activity engagement was measured by self-report of achievement of a weekly goal. At the end of each week, participants were asked to rate their perceived physical activity goals on an achievement scale from 0 (not met at all) to 5 (completed all physical activity goals). At the end of the fourth week (week 4), a research staff member visited each participant at home, reviewed the overall performance compared to the baseline, and discussed the long-term goals for each participant to maintain the activity (Figure 1).

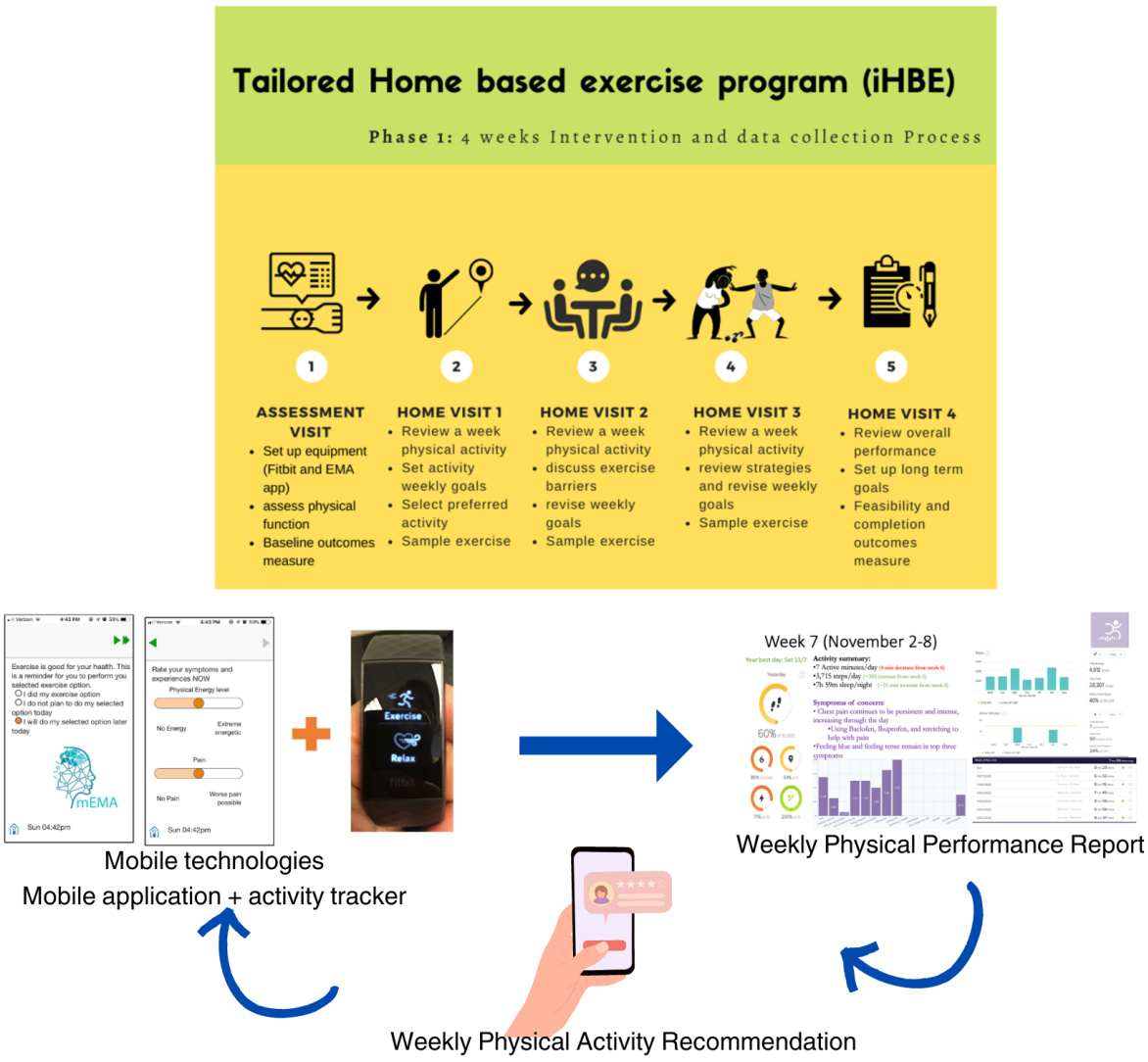

Figure 1: Study visits and mobile technology in the tailored Home-based Exercise Program

In the iHBE program, the physical activity tracking device was used to monitor the physical activity (step counts, active minutes) and sleep hours. The smartphone application was used to send a notification once a day (9:00 am) to remind the participant to complete the brief survey for daily symptoms and complete the weekly goals. The data from both physical activity tracking devices and applications were extracted from the research computer to generate the weekly performance report for each participant. The report was used by the research staff to adjust the weekly goals during the study visit.

Primary Outcome Measures

Recruitment and Retention were assessed from the research coordinator's records. Information on reasons why participants were ineligible or refused to participate was recorded.

Program Implementation was measured by the actual values on total contact time/each visit, the research team member's notes regarding the challenges of the intervention, and participants' perceptions of the intervention's content.

Adherence to the exercise goals was measured by participants' self-report. Participants were asked to complete a goal achievement survey (how much did you meet your physical activity goal(s) this week?) on a scale of 0 (not meet at all) to 5 (meet all physical activity goal(s)). Adherence to daily survey and step count monitor (wearing 24 hours/7 days for 4 weeks) were measured by the number of days with the missing data.

Adverse events were recorded. During the program, participants were asked to take note of any symptoms or discomfort during and after exercise. They were told to stop the exercise if experiencing unusual symptoms such as falling, lightheaded or fainting, shortness of breath, chest pain, severe and sharp pain, seek medical attention, and report to the research staff. For each home visit, a registered nurse (NL) or trained research staff discussed the participants' experience during the exercise at home.

Participants' Opinions and Acceptability of the intervention and the technology used in the program were measured using open-ended questions.

Secondary Outcome Measures

Pain was measured by the Patient-Reported Outcomes Measurement Information System (PROMIS) Short Form. Participants were asked to rate their worst, average, and current pain on a scale of 1 (no pain) to 5 (very severe). The sum of raw scores was translated into the T-score. A high score indicated high pain intensity. This measure had high internal consistency (Cronbach's $\alpha = .91$) [43].

Fatigue was measured by the Patient-Reported Outcome Measurement Information System (PROMIS) Short Form (V1.0-Fatigue 6a), a 6-item self-reported fatigue scale. Questions were asked regarding the characteristics of fatigue (frequency, duration, intensity) and its impact on physical, mental, and social activities. Participants were asked to rate their answers on five response options (1 or never to 5 or always). The reliability of the instrument (Cronbach's α) was 0.99 [43].

Resilience was measured by the Connor-Davidson Resilience Scale (CD-RISC). This 25-item self-report scale was rated on a 5-point Likert scale ranging from not true at all (0) to true nearly all the time (4). The total score ranged from 0 to 100; a higher score indicated greater resilience [44]. The reliability estimate for this measure was $\alpha > .90$ [45].

Well-being was measured by the self-reported Short-Form Health Survey (SF-36), a questionnaire that included eight subscales that evaluated physical function, social functioning, role limitations due to physical problems, role limitations due to emotional problems, and mental health, vitality, pain, and general health perceptions [46]. The total score on each subscale ranged from 0 to 100. The scores were divided into two summary scores: physical component summary (PCS: sum score of the physical function, role limitations due to physical problems, pain, and general health perceptions) and mental component summary (MCS: sum score of the social functioning, role limitations due to emotional problems, mental health, and vitality). A higher score indicated better well-being. The internal consistency of this subscale ranged from 0.693 to 0.924 [47].

Data Analysis

Descriptive statistics were used to characterize the feasibility of the recruitment. The number of screened participants, eligible participants, and adults who refused to be in the study and their rationale were examined and recorded as indicators of feasibility. The feasibility of delivering the program was evaluated by examining the number and timing of actual versus planned home visits and the duration of each visit. The total of weekly perceived physical activity goals achievement was calculated to evaluate each participant's engagement in activity. Descriptive statistics (mean and standard deviation) were used to analyze the symptoms, resilience, and well-being scores. A weekly average step count (7 days) from a physical activity tracking device (Fitbit) data was calculated. The percentage of change in steps was calculated by comparing the 4th week average step count to the baseline average step count. Data from the open-ended questions were analyzed by the first author (N.L.) using inductive thematic analysis.

Results

Eighty potential participants, identified through flyers, word of mouth, and referrals by providers, were screened by phone (Figure 2).

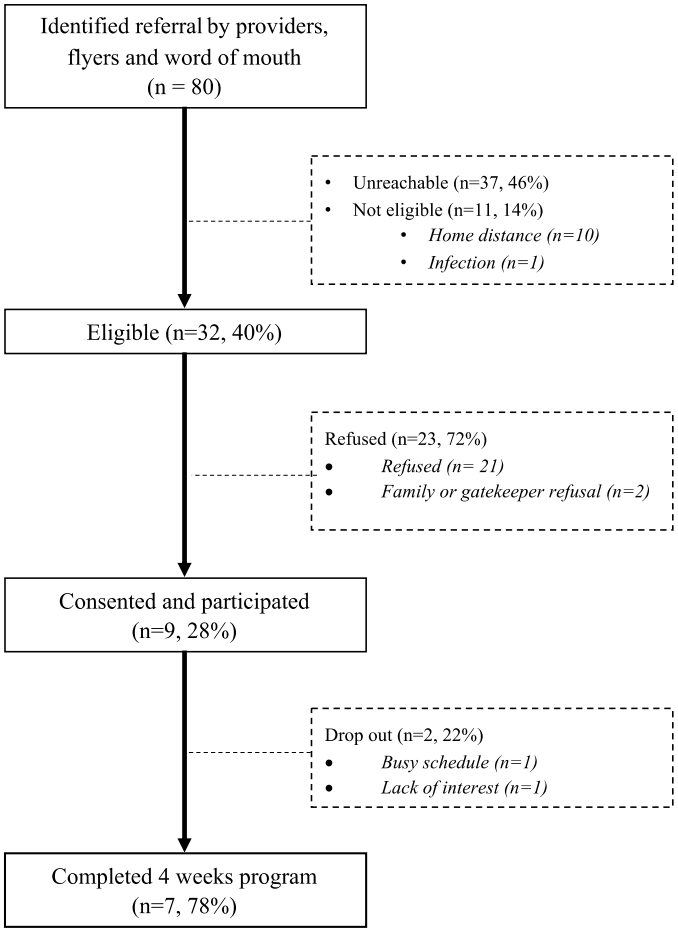

Figure 2: Flowchart of participants included in this study

Forty participants (40%) age range from 55 to 80 years (mean age 75.4, SD = 4.5) were eligible. Seven female and two male participants (28%) were eligible and consented. Participants' ages ranged from 56 to 78 years, with a mean age 70.9 (SD = 6.0) (Table 1). All participants were diagnosed with two or more chronic conditions (e.g., cancer, diabetes, hypertension). The age range of the participants who were eligible (55 to 80 years old) was similar to the age range of those who completed the program (56 to 78 years old).

Table 1. Demographic and Clinical Characteristics

Measures	Frequency	Percentage
Gender		
Female	7	77.7
Male	2	22.2
Age (Mean ± SD)	70.9 ± 6.0	
Education		
High School	1	11.1
Some College and College	8	88.9
Marital Status		
Married	5	55.5
Not Married	4	44.4
Race		
Black	4	44.4
White	5	55.5
Number of chronic conditions		
2 conditions	8	88.9
More than 2	1	11.1

SD= standard deviation

Primary Outcomes

Recruitment and Retention. Potential participants were referred by clinicians and electronic medical record screening. Forty-six percent were unreachable by phone (e.g., did not return the call, disconnected phone line) and 14% were not eligible because of the location distance, which was a challenge of home visit and active infection. Twenty-eight percent of eligible participants consented and participated in the 4-week program. The main reasons for refusal were unable or unwilling to allow home visits, hospitalization or being too sick to exercise, being overwhelmed with other obligations, or already in other research studies. During the program, two participants (22%) dropped out at week 2 due to busy schedules and lack of interest in exercising. During the intervention, one minor adverse event (elbow pain) after the exercise was reported; after a thorough investigation, it was determined that the incident was not related to the intervention.

Program Implementation. Five home visits were conducted. During the baseline home visit (T1: baseline, duration 45-60 minutes), a research staff member assessed each participant's home condition, goals, physical activity preferences, and physical condition, set up and trained the participant to use the physical activity tracking device (Fitbit) and smartphone app, and collected baseline outcome data. At home visits 1 to 4 (duration 45-60 minutes), a research staff member reviewed each participant's weekly physical activity and goal achievements and discussed challenges and adjusted the activity goals for the following week. Participants were asked to practice their exercises for 10-15 minutes at the visit. At home visit 5 (T2: completion, duration 45-60 minutes), a research staff member reviewed each participant's overall physical activity progress over the 4 weeks, discussed challenges and developed tailored long-term activity goals.

Before each study visit, a research staff member spent 10-20 minutes reviewing each participant's physical activity data (e.g., average step counts and sleep hours per day) and overall daily symptoms (collected daily from the smartphone application) change in the past 7 days. At the end of the study visit, the research staff member wrote the visit summary and challenges on the implementation in the study visit log (duration 5-10 minutes).

Program compliance. Participants were offered exercise options including the National Institute on Aging Go4Life exercises, walking, modified Otago exercises, and yoga at week 1 home visit. Yoga was selected by 3 participants while other options were chosen by 2 participants (Table 2). During the program, the participants' weekly step counts increased by 7-40% at week 4 from baseline (Table 2). One participant had an average step count decrease of 1% at week 4 compared to the baseline week. Three participants (43%) achieved 100% of their weekly goals for all 4 weeks with 71% (n=5) adhering to at least 75% of the weekly goals. The reasons for other participants who were unable to reach their weekly goals on some weeks included experiencing pain or other symptoms (n = 2), and family issues/emergencies (n = 2).

We asked the participants to wear the physical activity tracking device 7 days/week for 4 weeks (charging the battery when taking a shower) and report symptoms severity (for physical energy, pain, anxiety, depression, and sleep problems) on the smartphone application. Some participants reported the light from the physical activity tracker interrupted their sleep when wearing it at night and forgot to wear the device after taking it off for charging, which led to some days without step count data (adherence ranged from 6-11%). For the daily symptoms survey using the smartphone application, five participants (71%) adhered to at least 75% of the daily symptom survey (Table 2). Low daily survey adherence among 2 participants was due to technical difficulties with the smartphone, slow speed Wi-Fi, and technical glitches (e.g., a daily survey was not downloaded or took too long to download, did not receive notification). Overall, the recorded challenges included the following: (1) technical challenges (e.g., unable to sync the data, activity tracker or Bluetooth malfunction, unable to install the smartphone app on the participant's phone, or the different installation processes required for different smartphone platforms (iOS vs Android), (2) participants could not remember the information or goals discussed during the home visit, and, (3) staff members expressed the need for training in communicating with participants to set up goals.

Table 2. Step count changes at week 4 compared to baseline and missing data

Sample ID	Exercise Preferences	Step count		Goal achievement Score**	Adherence*** 28 days	
		Baseline (Mean ± SD)	Change at week 4		Physical activity tracker	Daily symptoms
iHBE-001	Yoga	6,342 ± 4,402.14	↓ 0.87%	16 (80%)	100%	82.14%
iHBE-002	Go4Life	6,501 ± 2,826.48	↑ 7.18%	20 (100%)	89.29%	89.29%
iHBE-003*	Yoga	2,968.60 ± 1,467	-	-	-	-
iHBE-004	Go4Life	9,546 ± 1,569	↑ 33.27%	20 (100%)	89.29%	78.57%
iHBE-005	Otago	4,037 ± 3631.37	↑ 32.20%	10 (50%)	92.86%	17.86%[a]
iHBE-006	Otago	2,570 ± 896.85	↑ 11.28%	13 (65%)	100%	21.43%[a]
iHBE-007	Yoga	10,775 ± 3,611.43	↑ 7.08%	15 (75%)	96.43%	75.00%
iHBE-008*	Walking	141 ± 43.84	-	-	-	-
iHBE-009	Walking	5,584 ± 3,195.64	↑ 40.08%	20 (100%)	100%	92.86%

* Participants dropped out after the baseline data collection.

** Goal achievement was measured on a scale of 0 (not meet at all) to 5 (completed all physical activity goals) weekly. The total goal achievement score is 20.

***Compliance with the % of days (during the 4-week program:28 days) without daily data (steps or daily symptoms)

[a] The missing data is due to a technical issue with the participant's smartphone

Participants' Opinions and Acceptability. After completing the 4 weeks intervention, participants were asked to answer open-ended questions regarding their opinions and suggestions for the program. Qualitative data relating to the intervention were categorized into two main themes: exercise program, and technology and technical issues. Exercise program. Participants found the exercise intervention feasible to follow and maintain. Participants highlighted three specific key elements they preferred in the program as follows.

Element 1: The ability to exercise at home and connect with providers.

> "*She [the research staff member] came to my house (yay, no more driving all over) to teach me some basic yoga and stretching*." (iHBE001)
>
> *"I like that I didn't have to go to any other site."* (iHBE002)
>
> *"Being able to work out in my home with my wonderful team (researchers). I wish the program duration*
>
> *were longer."* (iHBE005).

Element 2: Simple and achievable goals

> *"A simple program, with simple goals-but what a powerful change in both my physical and mental well-being."* (iHBE001)
>
> *"It serves as a regimental spark to do the exercises; has become nearly a routine part of our week and has produced a gratifying sense of accomplishment. Also, its request to adhere to a regular schedule and commitment."* (iHBE004)
>
> *"It concentrates on areas I can improve."* (iHBE006)
>
> *"Exercise program fits nicely with my usual exercise routine*." (iHBE009).

Element 3: Ability to monitor activity and sleep.

"I like the ability to track sleep, pulse, active minutes and calories." (iHBE009).

Technology and Technical Issues. The technologies used in the intervention included the physical activity tracker (Fitbit) and the smartphone application. While the physical activity tracker was generally well-liked and well-accepted among participants, technology glitches were reported for the smartphone application. The simplicity, ability to monitor health information, and long battery life were the most helpful features of the physical activity tracker.

> *"I found it (Fitbit) fairly simple to use and comfortable to wear. I liked that it held a long charge. I liked that it kept track of my steps and activity levels with accuracy. I liked the BPM measurement as well."* (iHBE001).
>
> *"Very helpful to track my activities and progress."* (iHBE005)
>
> *"I thoroughly enjoyed the access to data on a minute-to-minute, daily, weekly and monthly basis. Gained better understanding of sleep patterns and calorie burn."* (iHBE009)

However, many participants reported the physical activity tracker data (steps, sleeps hours) were inaccurate.

> "*It needs to be more accurate, especially with stairs. I do not think it helped me by being more aware of moving.*" (iHBE002)
>
> *"Poor! Very inaccurate! It reports an inflated, erroneous score for number of steps and number of stairs!*" (iHBE004)

Participants' opinions for the smartphone application were mixed. Some participants found the daily notification increased awareness of exercise and individual feelings.

> *"I think that this [the smartphone application] has made me more aware of the need to exercise and to plan the time to exercise which previously was ignored."* (iHBE002)
>
> *"[the smartphone application is] helpful in assessing my feeling of the day.*" (iHBE005)

However, some participants perceived that the daily notification and technical glitches were burdensome.

> *"I did not like the daily reminder feature for many reasons. First, the notification sound was barely audible, even when there was no other noise in the room. Further, the notification sound could NOT be detected unless you had the phone right next to you AND there was no other sound going on AND you were not distracted by something else at the exact moment."* (iHBE001)
>
> *"Technical glitches in the operation of applications is a nuisance. Sometimes having to answer questions severally and delayed downloading."* (iHBE009)

Secondary Outcomes

At the completion of the 4-week program, participants experienced a reduction in self reported pain intensity (6%) and fatigue (7%), and an improvement in resilience (11%) and well-being in both the physical (8%) and mental components (2%) (Table 3).

Table 3. Mean self-reported pain, fatigue, resilience, and well-being scores and percent change of the score at the completion visit compared to the baseline

Outcomes	Mean ± SD		Score change from baseline
	Baseline	Completion	
Pain	55.11 ± 9.64	52.09 ± 9.59	↓ 5.5%
Fatigue	53.84 ± 4.41	50.17 ± 6.82	↓ 6.8%
Resilience	29.25 ± 4.71	32.57 ± 3.82	↑ 11.4%
Well-being			
Physical component summary	241.38 ± 86.54	259.71 ± 91.09	↑ 7.6%
Mental component summary	285.17 ± 81.04	291.64 ± 57.45	↑ 2.3%

Discussion

Our study results support the safety and feasibility of the tailored home-based exercise program (iHBE) using mobile technology and a physical activity tracking device for cancer survivors with MCC and related pain problems. Similar to other home-based exercise studies that focused on a single chronic condition [16-18], no serious adverse events were reported among participants with MCC and pain. The four-week program reduced pain, and fatigue, and improved resilience and well-being. Of the seven participants who completed the program, 43% were able to fully adhere to the weekly exercise goals with 71% adhering to at least 75% of their weekly goals; the step count increases ranged from -1 to 40% from baseline. Adherence to at least 80% of wearing a physical activity tracking device daily (100%, n=7) and at least 75% reporting symptoms through smartphone application daily (71%, n=5) were acceptable.

The ability to safely exercise at home and co-create the personalized weekly physical activity goals with the research staff members enhanced the participants' self-efficacy and motivation to continue to exercise. The mobile technologies used in this study served as a tool to remind participants to exercise, provided immediate feedback, and communicated between the research team and participants. The study results provide preliminary evidence for the use of the tailored home exercise program as a supportive intervention to improve symptoms and overall well-being among cancer survivors with MCC.

A strength of this study was the inclusion of cancer survivors diagnosed with at least two chronic conditions, which had been underrepresented in previous studies. The use of a commercially available activity tracking device (Fitbit) and smartphone app helped us understand the physical activity pattern in participants' natural environment. The data obtained from the mobile technology provided additional objective information in guiding the tailoring of weekly exercise recommendations and setting up realistic physical activity goals. Tailoring the exercise recommendations, setting up weekly achievable goals, and allowing participants to co-create their exercise program based on their goals and preferences increased the participants' willingness to exercise and sustain an active lifestyle after the program.

Limitations of this exploratory study included the small sample size of participants and no control groups for comparison. While the study showed favorable results, the intervention effectiveness may have occurred by chance due to the low statistical power and uncontrolled observations. Larger clinical control trials are needed to confirm the findings. An additional limitation is the lack of assessment of cognitive and physical functions. Although we measured baseline physical activity (step counts and active min), set achievable physical activity goals with participants, and conducted multiple home visits, the lack of systematic assessment of participant's cognitive and physical function, and acuity could limit the effect of exercise on the outcomes. Finally, all participants of this pilot study were recruited from one geographic area (Maryland, USA), which could limit the generalizability of the findings to other populations.

Multiple challenges were noted by both participants and research staff members during the program. The first challenge was the low eligibility (40%) and enrollment (10%) rates in the recruitment process. We found that the change of contact address and phone numbers was a specific challenge among people who were referred from other research studies. Therefore, we changed the recruitment strategy from seeking referrals from other research studies to searching and identifying electronic medical records. The second challenge was the technical glitches for both physical activity tracking devices and the smartphone application. This challenge led us to create the technology training to increase mobile health literacy among research staff members to increase their confidence and competency in providing support to our participants.

Another challenge was the unavailability of the technology and internet connection at the participant's home. Due to the

low-income inclusion criteria and participants' age range, some participants did not have internet service or had a smartphone with limited capacity. Although we were able to rent a smartphone for the participant with the data plan, a more effective and sustainable solution is needed for future study. Lastly, a total of 5 weekly home visits was overwhelming for some participants because of their busy schedules. We found that most participants were able to safely exercise at home.

This pilot study was the first phase of our intervention trial. We used the listed limitations, challenges, and suggestions from participants and research staff to adjust recruitment and eligibility screening strategies and to adjust the intervention program for the phase 2 study and created a training plan and manual for research staff. The intervention adjustments included the following: (1) adding cognitive and physical function assessment, (2) re-adjusting the daily reminders and brief symptoms survey and creating a manual on how to use the physical activity tracker and the smartphone application for participants, and (3) expanding the duration and changing the intervention delivering method from 4 weekly home visits to 3 home visits (first two weeks and last week), and nine weekly phone visits. The phase 2 study will examine the effectiveness of the adjusted tailored intervention on symptoms and health outcomes.

Conclusion

In conclusion, the study results suggest that tailored home exercise is safe and feasible for cancer survivors with Multiple Chronic Conditions (MCC) and pain, who had previously been underrepresented in research. However, due to multiple challenges and limitations, adjustment of this exercise program is needed. With adjustment to the use of mobile technology and refinements in the process of tailoring interventions, this program can be an effective supportive intervention to help reduce cancer survivors' pain and fatigue and improve their well-being. Future randomized clinical control trials with a larger sample size are warranted to confirm these preliminary findings.

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