HHS Public Access

Author manuscript

J Cancer Surviv. Author manuscript; available in PMC 2022 August 01.

Published in final edited form as:

J Cancer Surviv. 2021 August ; 15(4): 554–563. doi:10.1007/s11764-020-00949-w.

Feasibility of a behavioral intervention using mobile health applications to reduce cardiovascular risk factors in cancer survivors: a pilot randomized controlled trial

Eric J. Chow[1,2], **David R. Doody**[1], **Chongzhi Di**[1], **Saro H. Armenian**[3], **K. Scott Baker**[1,2], **Jonathan B. Bricker**[1], **Ajay K. Gopal**[1,4], **Anna M. Hagen**[1], **Tyler G. Ketterl**[2], **Stephanie J. Lee**[1,4], **Kerryn W. Reding**[1,5], **Jeannette M. Schenk**[1], **Karen L. Syrjala**[1], **Sarah A. Taylor**[1], **Guangxing Wang**[1], **Marian L. Neuhouser**[1], **Jason A. Mendoza**[1,2]

[1]Fred Hutchinson Cancer Research Center, Seattle WA

[2]Department of Pediatrics, University of Washington, Seattle, WA

[3]City of Hope Medical Center, Duarte, CA

[4]Department of Medicine, University of Washington, Seattle, WA

[5]School of Nursing, University of Washington, Seattle, WA

Abstract

PURPOSE: Determine the feasibility of a remotely delivered mobile health (mHealth) supported intervention to improve diet and physical activity in hematologic malignancy survivors.

METHODS: Pilot randomized controlled trial of a 16-week intervention for improving diet and physical activity: individualized goal-setting (daily steps, sodium, percent saturated fat, percent added sugar intake) per feedback from mHealth trackers (Fitbit for activity; Healthwatch360 for diet), supplemented by a Facebook peer support group. Controls accessed the trackers without goal-setting or peer support. Everyone received standardized survivorship counseling with tailored advice from a clinician. Actigraphy and food frequency questionnaires assessed activity and diet at baseline and follow-up.

RESULTS: Forty-one participants (51.2% male; median age 45.1y; 7.0y from treatment) were randomized (24 intervention; 17 control). Fitbit and Healthwatch360 use were more common

Corresponding author: Eric J. Chow, MD, MPH, Fred Hutchinson Cancer Research Center, PO Box 19024, Mailstop M4-C308, Seattle WA 98109, ericchow@uw.edu, Phone: 206-667-7724, Fax: 206-667-5948.

Author contributions: study conception and design (EJC, CD, SHA, KSB, JBB, KWR, JMS, KLS, MLN, JAM); patient selection (AKG, SJL); data collection (EJC, AMH, SAT); data analysis (EJC, DRD, CD, GW); initial manuscript draft (EJC, DRD); critical review and revision (all authors).

COMPLIANCE WITH ETHICAL STANDARDS

The authors report no relevant disclosures. Funding was provided in part by P30 CA015704, R01 CA204378, and R01 CA215134 from the US National Institutes of Health, and in part by FHCRC philanthopic funds. All participants provided informed consent, and the protocol and procedures were approved by FHCRC's institutional review board (file number 10037).

among intervention versus control participants (75.0% versus 70.6% and 50.0% versus 17.7% of eligible days, respectively). Most intervention participants (66.7%) engaged with Facebook; overall, 91.7% interacted with the study's mHealth applications. While no comparisons in activity or dietary outcomes between intervention versus control group met statistical significance, the intervention was associated with greater reductions in the targeted dietary factors and improvements in Healthy Eating Index-2015 score, moderate-vigorous physical activity time, and daily steps. Participant retention at 6-months was 90.2%.

CONCLUSIONS: An intervention for cardiovascular risk reduction based on individualized goal-setting enhanced by mHealth and social media peer support was feasible and acceptable among cancer survivors.

IMPLICATIONS FOR CANCER SURVIVORS: Effective and easily disseminated strategies that improve diet and reduce sedentary time in this population are needed.

Registered in ClinicalTrials.gov (NCT03574012) on June 29, 2018.

Keywords

cancer survivorship; cardiovascular disease; diet; goal-setting; peer support; physical activity

INTRODUCTION

Hematologic malignancies require among the most intensive treatments of all cancers, including high-dose chemotherapy, radiation in many instances, and hematopoietic cell transplantation (HCT) for particular high-risk patients. While such treatments now often induce long-term cures, these survivors have been shown to be at significantly greater risk of premature cardiovascular disease due to therapy-related cardiotoxic exposures and a greater number of modifiable cardiovascular risk conditions and lifestyle factors compared with the general population and even other cancer survivors [1–3]. Observational studies suggest that reducing the burden of these risk conditions (i.e., hypertension, dyslipidemia, diabetes) and lifestyle factors (i.e., smoking, poor diet, physical inactivity) may substantially reduce the risk of serious cardiovascular events in this high-risk population, and that lifestyle modification may be as influential as control of cardiovascular risk conditions [4, 5].

Given the widespread popularity of smart phones and the increased availability of affordable consumer-grade health trackers and related mobile health applications (i.e., "mHealth apps"), an increasing number of studies are exploring the role of integrating these devices for health promotion purposes [6]. At the same time, social media may offer a strategy by which to engage and maintain participants' interest for intervention activities by providing a venue for social support and learning [7]. With these considerations in mind, we designed this 16-week pilot randomized controlled trial (RCT) to determine the feasibility, acceptability, and preliminary efficacy of an intervention based on existing consumer grade physical activity (PA) and dietary mHealth trackers and a widely used social media-based peer support group to supplement individualized goal-setting of PA and dietary goals among high-risk hematologic malignancy cancer survivors. This design allowed the intervention to be delivered completely remotely and without the need to develop any study-specific hardware or software.

The intervention's theoretical framework was guided by self-determination theory, based on increasing individual competence, autonomy, and relatedness. Self-determination theory has been a well-accepted model supporting physical activity and dietary intervention [8, 9]. In the study, regular interaction and feedback from the fitness and dietary trackers along with personalized goal-setting from study staff are expected to increase both competence and autonomy, while peer support is expected to increased relatedness. Results from this pilot study may inform the development of a larger, robustly powered and easily disseminated RCT for hematologic and other cancer survivors at increased risk of cardiovascular disease.

METHODS

Study participants

All participants were recruited from the Fred Hutchinson Cancer Research Center (FHCRC), an NCI-designated comprehensive cancer center. Eligibility criteria included: 1) current age 18 to 55 years; 2) receipt of HCT or any history of acute leukemia or lymphoma; 3) ≥5-years from initial cancer diagnosis; 4) currently in remission and not on any active anti-cancer therapies; 5) English-speaking; 6) access to a smart phone or computer with internet access; and 7) presence of ≥1 cardiovascular risk factor (i.e., medication(s) for hypertension, dyslipidemia, or diabetes; self-reported PA level <30 minutes/day; current smoker). Exclusion criteria included: 1) pre-existing ischemic heart disease or ongoing symptomatic cardiomyopathy; 2) active chronic graft versus host disease; and 3) currently pregnant. An initial cohort of HCT survivors (n=21) was enrolled and randomized between September-December 2018, and a second cohort of leukemia and lymphoma survivors (n=20) was enrolled and randomized between February-May 2019. All participants provided informed consent and the protocol and procedures were approved by FHCRC's institutional review board.

Measures

All participants were evaluated at FHCRC's Prevention Center research clinic at baseline prior to randomization. Height and weight (to calculate body mass index [BMI]) and blood pressure were collected using a standardized protocol. A fasting (10 hours) blood draw was obtained to assess lipid profile, glucose, insulin, and hemoglobin A1c. Cardiopulmonary reserve was assessed per submaximal exercise testing (up to 85% of the predicted maximum heart rate for age, or if the participant reported a rated perceived exertion score of 15 and a respiratory exchange ratio ≥1.00) and a 6-minute walk test (physiological cost index). These measures were repeated at FHCRC for all participants following the 16-week intervention period. At both clinic visits, participants also completed a questionnaire regarding their cardiovascular health history, medication adherence [10], PA levels [11], smoking history [12], health-related quality of life (PROMIS Global 10), health-related self-efficacy [13], behavior and attitudes towards exercise [14] and diet [15]. Participants also completed a separate food frequency questionnaire (FFQ) [16]. All participants were asked to wear a research grade triaxial accelerometer (Actigraph GT3X, ActiGraph LLC, Pensacola, Florida) at the hip for 7 days prior to and immediately after the intervention period [17, 18]. Research staff who obtained the in-person assessments and processed the FFQ and actigraphy data were blinded to randomization assignment.

Intervention and Control Conditions

The study schema is shown in Supplementary Figure 1. Following the baseline assessment, all participants received a 30-minute telephone-based review of a National Academy of Medicine-recommended cancer treatment summary and survivorship care plan [19], based on abstracted medical records, from a study advanced practice provider blinded to randomization assignment and following a standardized script. The telephone session included the development of a mutually-agreed upon action plan directed at any measurable cardiovascular abnormalities (e.g., hypertension, dyslipidemia, diabetes) [20]. This included a discussion of potential barriers (and solutions) to successful implementation of the action plan. All participants also received complimentary access to a commercially available consumer-oriented fitness tracker (Fitbit Flex wearable wristband and mHealth app; Fitbit, Inc., San Francisco, California) and a diet tracking app (Healthwatch360; GB Healthwatch, San Diego, California). These apps were in part chosen due to their abilities to provide the specific feedback necessary for the study's goal-setting (further described below) and to enable the research team to directly access participant data from a researcher portal. Current smokers also received access to a smartphone-based smoking cessation app, iCanQuit, whose treatment model has broad empirical support [21, 22]. Given the expected small numbers of current smokers (~10% based on our prior research [4]) and their predicted high cardiovascular risk, current smokers were non-randomly assigned to the intervention arm, while remaining participants were randomized 1:1 to intervention:control, stratified by sex.

Over the course of the 16-week intervention period (January-April 2019 for cohort 1; May-September 2019 for cohort 2), intervention participants received weekly individualized goal-setting to increase daily steps tracked by Fitbit and reduce three dietary components strongly associated with impacts on cardiovascular health (sodium, saturated fats, and added sugars; Table 1) [23] tracked using Healthwatch360. Study staff had direct access to participant's Fitbit and Healthwatch360 data through an app-specific research portal. Using this information, staff created individualized weekly step count goals based on the past week's daily average steps. Study staff also updated dietary goals monthly based on a one-week period (occurring once every four weeks) where participants were asked to enter consumed foods and beverages on the Healthwatch360 app. Goals for participants were communicated via text messaging or by email per participant preference. Staff also sent intervention participants text messages related to PA and diet twice per week to encourage and remind participants about their goals [24]. Finally, intervention participants also had access to a private, invitation-only study-specific Facebook group (optional) where staff provided intervention participants with supportive messaging as well as links to educational information on the health benefits of exercise and diet based on a predetermined script (Supplemental Table 1). Participants who declined to join the group received links to the educational information by email instead. The Facebook group, moderated by staff, also was intended to be a forum for participants to encourage and discuss their experiences with the study's PA and dietary components.

Control participants, while having access to the Fitbit tracker and Healthwatch360 app, did not receive reminders to use them, and received no coaching on goal-setting or feedback on

their activity or diet. They only received a reminder halfway through the intervention period reminding them their follow-up assessments would occur in approximately two months.

Statistical Analysis

The primary aim of the study was feasibility. Metrics defined a priori, and informed by our prior work [25, 24], included: 1) >20% participation rate with >80% retention rate over the intervention period; 2) >90% interaction with mHealth apps among intervention participants over the intervention period. Specifically, app usage was defined as the number of days that the fitness tracker recorded ≥500 steps (goal ≥50%), number of days the diet tracking app recorded ≥500 calories (goal ≥75%), and number of participants who logged into the Facebook group and interacted at least once (e.g., viewing or liking a post, or posting a comment themselves).

Secondary aims focused on preliminary efficacy and effect size needed to power any future RCT. Outcomes of interest were: 1) changes in PA as measured by actigraphy, specifically sedentary time, light PA, and moderate-to-vigorous PA (MVPA); and 2) changes in diet as measured by FFQ, specifically, sodium (mg/day), saturated fat (as % of total energy/day), added sugars (as % of total energy/day), and overall diet quality per the 2015 Healthy Eating Index (HEI-2015) [26]. For actigraphy-derived PA data, we applied the Choi algorithm on minute-level counts data to detect nonwear periods and applied commonly used data quality standards to define valid wear time [27]. We used validated Troiano cut-points to define sedentary time (<100 counts/minute), light PA (100–2019 counts/minute), and moderate-to-vigorous PA (MVPA; ≥2020 counts/minute) [27, 28]. We examined change from baseline by randomization status using mixed-effects linear regression, adjusted for sex, wear time (PA outcomes only), and study cohort. Finally, as part of a pre-planned subanalysis, we also examined differences in outcomes among intervention subjects by degree of Facebook engagement (above versus below the median number of interactions). All comparisons were two-sided, with p-values <0.05 considered statistically significant. Analyses were done using STATA (version 16, StataCorp, College Station, Texas).

Qualitative Interviews and Analyses

Following the intervention period, we conducted 10 optional individual semi-structured qualitative interviews with intervention participants by telephone to assess their perception of the study's acceptability (i.e., adoptability) [29]. Staff without prior interactions with participants used a standardized script to explore study experiences and barriers to participation, including those related to the study's survivorship care counseling, PA and dietary trackers and apps, and social media platform [30]. Interviews were digitally recorded and transcribed verbatim. Two staff members independently coded and analyzed the transcripts using thematic analysis to identify themes and subthemes [31]. A third staff member adjudicated any inconsistent codes.

RESULTS

Overall, 420 potentially eligible participants whose last known address was in Washington State were identified from the institutional database and approached by mail (Supplementary

Figure 1). Of these, we were unable to locate 68 participants, 68 refused, 69 were found to be ineligible, and 174 were still in process when we met our accrual goal (n=41; 14.4% of those initially approached, not lost to follow-up, and not known to be ineligible). The median age of the 41 enrolled participants was 45.1 years (range 20.2–54.8), and participants were 7.0 years (range 4.6–9.8) from last cancer treatment or transplant (Table 2). Most participants had received prior HCT (63.4%) and some radiation exposure (53.7%). Notably the self-reported time spent doing physical activity (median 180 minutes/week) met national recommendations for ≥150 minutes/week (i.e., ≥21.4 minutes/day) of moderate activity [32]. While mean BMI was in the overweight range (29.0±6.4 kg/m^2), blood pressures and lipid profiles were generally not very abnormal. In contrast, mean insulin resistance was high and cardiopulmonary reserve (physiological cost index, predicted VO_2 max) appeared low for age.

Overall, 91.7% of intervention subjects interacted with the study's mHealth apps. This included 75.0% of intervention participants meeting goals for regular fitness tracker use, 50.0% meeting goals for regular dietary tracker use, and 66.7% meeting goals for social media interaction. Not surprisingly, regular fitness and dietary tracker usage (using the same definitions) among control subjects was lower (70.6% and 17.7%, respectively). Overall study retention following the intervention period at 6 months was 90.2% (four lost to follow-up out of 41).

In contrast to self-reported PA, mean actigraphy-measured levels of MVPA at baseline were slightly below national recommendations for both groups (intervention 18.9±20.7 minutes/day; control 20.2±11.9 minutes/day) with high amounts of sedentary time (intervention 604.3±97.2 minutes/day; control 585.7±114.5 minutes/day). Adjusted mixed models found no significant differences between the two groups over time with respect to sedentary time, light or MVPA time, or total steps, although the direction of effect favored the intervention group (Table 3). For the targeted dietary factors, baseline sodium intake was high in both groups (intervention 3,633±1,500 mg/day; control 3,383±1,197 mg/day) but percent added sugars and percent saturated fat were close to recommended goals (<10% of daily calories; Tables 1 and 3). Analyses of these FFQ-derived measures of dietary factors over time showed no significant differences between the two groups, although the direction of effect generally favored the intervention group. Both PA and diet results, including direction of effects, were similar when comparisons were limited to those with paired data and if non-randomly assigned smokers were excluded (data not shown). When quality of life and health-related self-efficacy were examined, the intervention was associated with improvements, although the differences between arms were not statistically significant (Table 3). Finally, no significant differences between the intervention versus control group were observed in any of the cardiovascular health measurements between baseline and follow-up (data not shown).

When outcomes among intervention participants were analyzed by degree of Facebook engagement, those with greater engagement reportedly significantly greater change in health-related self-efficacy (+11.9 versus −4.3; p=0.004) and diet quality (percent saturated fat −1.6% versus +1.6% and HEI +5.2 versus −3.3; both p=0.01) compared with those with lower engagement. The magnitude of change for sedentary time (−18.8 versus +22.7

minutes/day; p=0.45) and MVPA (+7.2 versus +1.4 minutes/day; p=0.54) was also larger among those with greater Facebook engagement.

Ten intervention participants (out of 11 approached) completed qualitative interviews with study staff to assess study acceptability. Overall, most expressed satisfaction with their experience overall, including increased awareness of their health risks and continued interest in improving targeted lifestyle habits (Table 4). In addition to key facilitators and barriers identified from at least 5 of those surveyed, participants also provided various suggestions for enhancing the intervention. The most common suggestions included increasing participant accountability with more frequent check-ins (including via apps or by personal calls, plus opportunities to revise or further tailor one's initial action plan) as well as more information and training on how to use the apps more effectively, particularly the diet tracker.

DISCUSSION

Overall, our results showed that a 16-week multiple mHealth app-based lifestyle and counseling intervention among intensively treated cancer survivors was feasible. While we did not meet our predefined participation rate of 20%, we believe that had we used more aggressive follow-up strategies (e.g., multiple mailings and phone calls) and if we had not reached our enrollment cap, we could have met the 20% threshold. Other barriers to participation, such as requiring two in-person visits to the cancer center, could be modified to rely instead on remote procedures (e.g., home visits). Participant retention met feasibility aims (>80%, including among controls), and among intervention subjects, >90% interacted with the study's various mHealth apps. As a pilot study not powered for efficacy testing, it was not surprising that we did not observe significant differences in our PA and dietary outcomes. However, the direction of effect supported the intervention and provided important information on potential effect sizes that can inform the design of a more robustly powered follow-up study [33]. Finally, while a randomized design is not essential to determine the feasibility of a pilot intervention, given that any future, robustly powered intervention study would likely require a randomized design, incorporating randomization at the pilot study phase allowed us to gain valuable information specific to both the intervention and control conditions [33].

Research from our group and many others have shown that HCT and hematologic malignancy survivors are at significantly increased risk of early cardiovascular disease [1–3, 34–36], and that potentially modifiable risk factors such as PA, diet, and smoking remain associated with cardiovascular risk in heavily treated cancer survivors [4, 5]. There is a large body of evidence from the general population that shows that behavioral counseling targeting healthful diet and PA is modestly effective [38, 23]. The effectiveness of such interventions may be increased when they are more tailored for a narrower population (e.g., those with cardiovascular risk factors) and if they are more intensive and accessible in real-time when needed [39]. Among cancer survivors, a mixed body of evidence supports the efficacy of tailored interventions targeting PA, and to a lesser degree, diet quality [40, 41]. However, many of the more effective studies have been fairly intensive with multiple in-person or telephone sessions [42, 43]. There also remains a preponderance of studies

focused on white women with breast cancer, and the evidence for other cancer survivor populations is more limited [40, 41]. With these gaps in mind, our pilot intervention involving both men and women treated primarily for hematologic malignancies and targeting both PA and diet extends the available literature.

mHealth interventions are an attractive strategy to overcome these barriers, given the growing sophistication of wearable and consumer-grade trackers and apps, and the widespread penetration of smart phones across different racial/ethnic groups [44]. While mHealth RCTs targeting PA in the general population have generally shown only modest effects [45], mHealth interventions for cancer survivors specifically have been limited for both PA and diet [46, 41]. Among cancer survivors, goal-setting and graded tasks were among factors associated with more efficacious PA interventions and higher adherence [40]. A focus on walking as the primary PA intervention modality has also been shown to be preferred by cancer survivors [47]. For diet interventions, modest improvements in diet quality are possible, although in isolation they tend not be associated with significant anthropometric or physiologic changes, suggesting a need for multi-faceted interventions [41, 48]. With these results in mind, we believe our multi-faceted intervention based on goal-setting with gradual changes in PA and dietary factor shows promising preliminary feasibility and acceptability.

Based on our study's experience and supplemented by qualitative feedback from participants, modifications to study procedures, such as greater guidance on the use of the dietary tracker and increasing participants' sense of accountability by providing more frequent reminders or check-in's may further improve interaction, adherence, and efficacy in the future. Additional strategies that may increase the efficacy of the intervention include: 1) longer intervention period, where 6 months is a common benchmark, followed by a less intensive "maintenance" phase to help sustain any intervention effects; 2) more ambitious goal-setting, perhaps supplemented by a more sophisticated PA tracker capable of reporting MVPA, not just steps; 3) limiting participants to those who are highly sedentary and have below average diet quality at baseline; and 4) increasing engagement on the social media platform (the study did not require use of a social media platform as an eligibility criteria). While we non-randomly assigned current smokers to the intervention arm, our study did not assess those participants' interest in quitting. Any future study that incorporates a smoking cessation app as part of a multi-faceted mHealth intervention would need to be more proactive in encouraging engagement with that app.

Our study has some additional limitations, which could be addressed in any future revised protocol. Besides being a pilot trial with limited sample size recruited from a single institution, there was also limited racial/ethnic diversity (i.e., 79% white non-Hispanic). However, mHealth-supported interventions may help reduce racial/ethnic disparities, in that smartphone ownership is similar (~80%) across different racial/ethnic groups in the US [44]. Studies targeting other groups will need to consider whether interventions need to be culturally tailored to be more acceptable to participants from different racial/ethnic backgrounds [49]. A longer intervention period, besides being more likely to lead to adoption of longer-term lifestyle change [50], would also be more likely to detect any improvements in participants' cardiometabolic profiles [39, 51].

In summary, cancer survivors generally have low adherence to healthy lifestyle recommendations. While oncology providers are invested in helping cancer patients and survivors address these issues, significant barriers exist (e.g., lack of time, training, resources, and reimbursement) [51, 52]. In this void, remote-based and easily disseminated mHealth apps may play an important role. Our results provide preliminary evidence that a multi-faceted mHealth-supported lifestyle intervention, using existing platforms while personalizing goals and content, is feasible.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

REFERENCES

1. Hull MC, Morris CG, Pepine CJ, Mendenhall NP. Valvular dysfunction and carotid, subclavian, and coronary artery disease in survivors of hodgkin lymphoma treated with radiation therapy. JAMA. 2003;290(21):2831–7. [PubMed: 14657067]
2. Baker KS, Ness KK, Steinberger J, Carter A, Francisco L, Burns LJ et al. Diabetes, hypertension, and cardiovascular events in survivors of hematopoietic cell transplantation: a report from the bone marrow transplantation survivor study. Blood. 2007;109(4):1765–72. [PubMed: 17047152]
3. Tichelli A, Bhatia S, Socie G. Cardiac and cardiovascular consequences after haematopoietic stem cell transplantation. Br J Haematol. 2008;142(1):11–26. [PubMed: 18430191]
4. Chow EJ, Baker KS, Lee SJ, Flowers ME, Cushing-Haugen KL, Inamoto Y et al. Influence of conventional cardiovascular risk factors and lifestyle characteristics on cardiovascular disease after hematopoietic cell transplantation. J Clin Oncol. 2014;32(3):191–8. [PubMed: 24297944]
5. Leger KJ, Baker KS, Cushing-Haugen KL, Flowers MED, Leisenring WM, Martin PJ et al. Lifestyle factors and subsequent ischemic heart disease risk after hematopoietic cell transplantation. Cancer. 2018;124(7):1507–15. [PubMed: 29315507]
6. Schoeppe S, Alley S, Van Lippevelde W, Bray NA, Williams SL, Duncan MJ et al. Efficacy of interventions that use apps to improve diet, physical activity and sedentary behaviour: a systematic review. Int J Behav Nutr Phys Act. 2016;13(1):127. [PubMed: 27927218]
7. Balatsoukas P, Kennedy CM, Buchan I, Powell J, Ainsworth J. The Role of Social Network Technologies in Online Health Promotion: A Narrative Review of Theoretical and Empirical Factors Influencing Intervention Effectiveness. J Med Internet Res. 2015;17(6):e141. [PubMed: 26068087]
8. Teixeira PJ, Carraca EV, Markland D, Silva MN, Ryan RM. Exercise, physical activity, and self-determination theory: a systematic review. Int J Behav Nutr Phys Act. 2012;9:78. [PubMed: 22726453]
9. Teixeira PJ, Carraca EV, Marques MM, Rutter H, Oppert JM, De Bourdeaudhuij I et al. Successful behavior change in obesity interventions in adults: a systematic review of self-regulation mediators. BMC Med. 2015;13:84. [PubMed: 25907778]
10. Morisky DE, Green LW, Levine DM. Concurrent and predictive validity of a self-reported measure of medication adherence. Med Care. 1986;24(1):67–74. [PubMed: 3945130]
11. Godin G, Jobin J, Bouillon J. Assessment of leisure time exercise behavior by self-report: a concurrent validity study. Can J Public Health. 1986;77(5):359–62. [PubMed: 3791117]
12. Centers for Disease Control and Prevention. Behavioral Risk Factor Surveillance System. http://www.cdc.gov/brfss/. Accessed 1 July 2020.
13. Schwarzer R, Luszczynska A. Self-efficacy http://cancercontrol.cancer.gov/brp/research/constructs/self_efficacy.html. Accessed 1 July 2020.
14. Markland D, Tobin V. A modification to the behavioural regulation in exercise questionnaire to include an assessment of amotivation. J Sport Exercise Psy. 2004;26(2):191–6.

15. Hearty AP, McCarthy SN, Kearney JM, Gibney MJ. Relationship between attitudes towards healthy eating and dietary behaviour, lifestyle and demographic factors in a representative sample of Irish adults. Appetite. 2007;48(1):1–11. [PubMed: 17049407]
16. Patterson RE, Kristal AR, Tinker LF, Carter RA, Bolton MP, Agurs-Collins T. Measurement characteristics of the Women's Health Initiative food frequency questionnaire. Ann Epidemiol. 1999;9(3):178–87. [PubMed: 10192650]
17. Trost SG, McIver KL, Pate RR. Conducting accelerometer-based activity assessments in field-based research. Med Sci Sports Exerc. 2005;37(11 Suppl):S531–43. [PubMed: 16294116]
18. Sasaki JE, John D, Freedson PS. Validation and comparison of ActiGraph activity monitors. J Sci Med Sport. 2011;14(5):411–6. [PubMed: 21616714]
19. Committee on Cancer Survivorship: Improving Care and Quality of Life, National Cancer Policy Board. From Cancer Patient to Cancer Survivor: Lost in Transition. In: Hewitt M, Greenfield S, Stovall E, editors. Washington, D.C.: Institute of Medicine and National Research Council, National Academies Press; 2006.
20. Schulman-Green D, Bradley EH, Knobf MT, Prigerson H, DiGiovanna MP, McCorkle R. Self-management and transitions in women with advanced breast cancer. J Pain Symptom Manage. 2011;42(4):517–25. [PubMed: 21444183]
21. Bricker JB, Watson NL, Mull KM, Heffner JL, editors. Design of the iCanQuit app for smoking cessation and update on its evaluation in a large US randomized controlled trial. Annual Meeting of the Society for Research on Nicotine and Tobacco; 2019; San Francisco, CA.
22. O'Connor M, Whelan R, Bricker J, McHugh L. Randomized Controlled Trial of a Smartphone Application as an Adjunct to Acceptance and Commitment Therapy for Smoking Cessation. Behav Ther. 2020;51(1):162–77. [PubMed: 32005334]
23. Van Horn L, Carson JA, Appel LJ, Burke LE, Economos C, Karmally W et al. Recommended Dietary Pattern to Achieve Adherence to the American Heart Association/American College of Cardiology (AHA/ACC) Guidelines: A Scientific Statement From the American Heart Association. Circulation. 2016;134(22):e505–e29. [PubMed: 27789558]
24. Miropolsky EM, Baker KS, Abbey-Lambertz M, Syrjala K, Chow EJ, Ceballos R et al. Participant Perceptions on a Fitbit and Facebook Intervention for Young Adult Cancer Survivors: A Qualitative Study. J Adolesc Young Adult Oncol. 2020;9(3):410–7. [PubMed: 31928489]
25. Mendoza JA, Baker KS, Moreno MA, Whitlock K, Abbey-Lambertz M, Waite A et al. A Fitbit and Facebook mHealth intervention for promoting physical activity among adolescent and young adult childhood cancer survivors: A pilot study. Pediatr Blood Cancer. 2017;64(12). doi:10.1002/pbc.26660.
26. Krebs-Smith SM, Pannucci TE, Subar AF, Kirkpatrick SI, Lerman JL, Tooze JA et al. Update of the Healthy Eating Index: HEI-2015. J Acad Nutr Diet. 2018;118(9):1591–602. [PubMed: 30146071]
27. Choi L, Liu Z, Matthews CE, Buchowski MS. Validation of accelerometer wear and nonwear time classification algorithm. Med Sci Sports Exerc. 2011;43(2):357–64. [PubMed: 20581716]
28. Troiano RP, Berrigan D, Dodd KW, Masse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. Med Sci Sports Exerc. 2008;40(1):181–8. [PubMed: 18091006]
29. Ayala GX, Elder JP. Qualitative methods to ensure acceptability of behavioral and social interventions to the target population. J Public Health Dent. 2011;71 Suppl 1:S69–79. [PubMed: 21656958]
30. Krueger R Developing Questions for Focus Groups: Focus Group Kit #3. Thousand Oaks, CA: Sage Publications; 1998.
31. Braun V, Clarke V. Using thematic analysis in psychology. Qualitative Research in Psychology. 2006;3(2):77–101.
32. Centers for Disease Control and Prevention. Physical activity for everyone. http://www.cdc.gov/physicalactivity/everyone/guidelines/index.html. Accessed 1 July 2020.
33. Czajkowski SM, Powell LH, Adler N, Naar-King S, Reynolds KD, Hunter CM et al. From ideas to efficacy: The ORBIT model for developing behavioral treatments for chronic diseases. Health Psychol. 2015;34(10):971–82. [PubMed: 25642841]

34. Chow EJ, Mueller BA, Baker KS, Cushing-Haugen KL, Flowers ME, Martin PJ et al. Cardiovascular hospitalizations and mortality among recipients of hematopoietic stem cell transplantation. Ann Intern Med. 2011;155(1):21–32. [PubMed: 21727290]
35. Armenian SH, Sun CL, Vase T, Ness KK, Blum E, Francisco L et al. Cardiovascular risk factors in hematopoietic cell transplantation survivors: role in development of subsequent cardiovascular disease. Blood. 2012;120(23):4505–12. [PubMed: 23034279]
36. van Nimwegen FA, Schaapveld M, Janus CP, Krol AD, Petersen EJ, Raemaekers JM et al. Cardiovascular disease after Hodgkin lymphoma treatment: 40-year disease risk. JAMA Intern Med. 2015;175(6):1007–17. [PubMed: 25915855]
37. Patnode CD, Evans CV, Senger CA, Redmond N, Lin JS. Behavioral Counseling to Promote a Healthful Diet and Physical Activity for Cardiovascular Disease Prevention in Adults Without Known Cardiovascular Disease Risk Factors: Updated Evidence Report and Systematic Review for the US Preventive Services Task Force. JAMA. 2017;318(2):175–93. [PubMed: 28697259]
38. LeFevre ML, Force USPST. Behavioral counseling to promote a healthful diet and physical activity for cardiovascular disease prevention in adults with cardiovascular risk factors: U.S. Preventive Services Task Force Recommendation Statement. Ann Intern Med. 2014;161(8):587–93. [PubMed: 25155419]
39. Turner RR, Steed L, Quirk H, Greasley RU, Saxton JM, Taylor SJ et al. Interventions for promoting habitual exercise in people living with and beyond cancer. Cochrane Database Syst Rev. 2018;9:CD010192. doi:10.1002/14651858.CD010192.pub3.
40. Burden S, Jones DJ, Sremanakova J, Sowerbutts AM, Lal S, Pilling M et al. Dietary interventions for adult cancer survivors. Cochrane Database Syst Rev. 2019;2019(11). doi:10.1002/14651858.CD011287.pub2.
41. Demark-Wahnefried W, Morey MC, Sloane R, Snyder DC, Miller PE, Hartman TJ et al. Reach out to enhance wellness home-based diet-exercise intervention promotes reproducible and sustainable long-term improvements in health behaviors, body weight, and physical functioning in older, overweight/obese cancer survivors. J Clin Oncol. 2012;30(19):2354–61. [PubMed: 22614994]
42. Courneya KS, Vardy JL, O'Callaghan CJ, Friedenreich CM, Campbell KL, Prapavessis H et al. Effects of a Structured Exercise Program on Physical Activity and Fitness in Colon Cancer Survivors: One Year Feasibility Results from the CHALLENGE Trial. Cancer Epidemiol Biomarkers Prev. 2016;25(6):969–77. [PubMed: 27197271]
43. Perrin A, Turner E. Smartphones help blacks, Hispanics bridge some - but not all - digital gaps with whites. Pew Research Center. https://www.pewresearch.org/fact-tank/2019/08/20/smartphones-help-blacks-hispanics-bridge-some-but-not-all-digital-gaps-with-whites/. Accessed 1 July 2020.
44. Direito A, Carraca E, Rawstorn J, Whittaker R, Maddison R. mHealth Technologies to Influence Physical Activity and Sedentary Behaviors: Behavior Change Techniques, Systematic Review and Meta-Analysis of Randomized Controlled Trials. Ann Behav Med. 2017;51(2):226–39. [PubMed: 27757789]
45. Haberlin C, O'Dwyer T, Mockler D, Moran J, O'Donnell DM, Broderick J. The use of eHealth to promote physical activity in cancer survivors: a systematic review. Supportive care in cancer : official journal of the Multinational Association of Supportive Care in Cancer. 2018;26(10):3323–36.
46. Wong JN, McAuley E, Trinh L. Physical activity programming and counseling preferences among cancer survivors: a systematic review. Int J Behav Nutr Phys Act. 2018;15(1):48. [PubMed: 29879993]
47. Vargas AJ, Schully SD, Villani J, Ganoza Caballero L, Murray DM. Assessment of Prevention Research Measuring Leading Risk Factors and Causes of Mortality and Disability Supported by the US National Institutes of Health. JAMA Netw Open. 2019;2(11):e1914718. [PubMed: 31702797]
48. McNulty J, Kim W, Thurston T, Kim J, Larkey L. Interventions to Improve Quality of Life, Well-Being, and Care in Latino Cancer Survivors: A Systematic Literature Review. Oncol Nurs Forum. 2016;43(3):374–84. [PubMed: 27105198]

49. Amireault S, Fong AJ, Sabiston CM. Promoting Healthy Eating and Physical Activity Behaviors: A Systematic Review of Multiple Health Behavior Change Interventions Among Cancer Survivors. Am J Lifestyle Med. 2018;12(3):184–99. [PubMed: 30202391]

50. US Preventive Services Task Force, Grossman DC, Bibbins-Domingo K, Curry SJ, Barry MJ, Davidson KW et al. Behavioral Counseling to Promote a Healthful Diet and Physical Activity for Cardiovascular Disease Prevention in Adults Without Cardiovascular Risk Factors: US Preventive Services Task Force Recommendation Statement. JAMA. 2017;318(2):167–74. [PubMed: 28697260]

51. Tollosa DN, Tavener M, Hure A, James EL. Adherence to multiple health behaviours in cancer survivors: a systematic review and meta-analysis. J Cancer Surviv. 2019;13(3):327–43. [PubMed: 30993648]

52. Ligibel JA, Jones LW, Brewster AM, Clinton SK, Korde LA, Oeffinger KC et al. Oncologists' Attitudes and Practice of Addressing Diet, Physical Activity, and Weight Management With Patients With Cancer: Findings of an ASCO Survey of the Oncology Workforce. J Oncol Pract. 2019;15(6):e520–e8. [PubMed: 31095436]

TABLE 1.

Goal-setting categories for intervention participants

Goals	Ideal	Borderline	Not ideal
Average daily steps	8,000–9,999 steps (doing great; can set weekly goal to increase by 10%, up to ≥10,000) If ≥10,000 steps (maintain, and try to also achieve ≥60 active minutes)	5,000–7,999 steps (weekly goal will be to increase daily steps by 10%; e.g., if prior week's average was 6,000, then the new goal would be to try to average 6,600 steps/day that week)	<5,000 steps (weekly goal will be to increase daily steps by 500; e.g., if prior week's average was 3,000, then the new goal would be to average 3,500 steps/day that week)
Daily *%* added sugars	<10% (maintain)	10–14% (try to reach <10% by next month's assessment)	≥15% (try to reach 10–14% by next month's assessment, then try to maintain for another month at that level before trying to achieve ideal range the following month)
Daily % saturated fat	<10% (maintain)	10–14% (try to reach <10% by next month's assessment)	≥15% (try to reach 10–14% by next month's assessment, then try to maintain for another month at that level before trying to achieve ideal range the following month)
Daily sodium	<2300 mg (maintain)	2300–3999 mg (try to reduce by 500 mg each month)	≥4000 mg (try to reduce by 500 mg each month)

TABLE 2.

Demographic and clinical characteristics of study participants

Characteristics	Intervention N=24	Control N=17	Overall N=41
Female (%)	11 (45.8)	9 (52.9)	20 (48.8)
White, non-Hispanic (%)	19 (79.2)	13 (76.5)	32 (78.0)
Median current age (range)	44.0 (20.9–54.0)	46.0 (20.2–54.8)	45.1 (20.2–54.8)
Median age at diagnosis, years (range)	36.6 (12.1–47.6)	37.5 (12.0–48.8)	37.5 (12.0–48.8)
Underlying diagnosis (%)			
Leukemia	10 (41.7)	4 (23.5)	14 (34.1)
Lymphoma	13 (54.2)	13 (76.5)	26 (63.4)
Other[a]	1 (4.2)	0	1 (2.4)
History of hematopoietic cell transplant (%)	14 (58.3)	12 (70.6)	26 (63.4)[b]
College graduate (%)	13 (54.2)	11 (64.7)	24 (58.5)
Currently married/partnered (%)	15 (62.5)	11 (64.7)	26 (63.4)
History of survivorship clinic attendance (%)	13 (54.2)	7 (41.2)	20 (48.8)
Median reported activity, minutes/week (IQR)[c]	165 (50–310)	180 (70–300)	180 (70–300)
Cardiovascular risk factors (%)			
Hypertension requiring medication	4 (16.7)	4 (23.5)	8 (19.5)
Dyslipidemia requiring medication	3 (12.5)	5 (29.4)	8 (19.5)
Diabetes requiring medication	5 (20.8)	1 (5.9)	6 (14.6)
Current smoker[d]	5 (20.8)	0	5 (20.8)
Clinical measurements, mean (SD)			
BMI, kg/m^2	28.6 (6.5)	29.6 (6.3)	29.0 (6.4)
Systolic blood pressure, mmHg	124 (15)	125 (9)	125 (12)
Diastolic blood pressure, mmHg	77 (12)	80 (9)	78 (11)
Low density lipoprotein, mg/dL	119 (23)	112(35)	116 (28)
Triglyceride, mg/dL	110 (47)	192 (85)	144 (76)
HOMA-IR	4.22 (5.90)	4.29 (3.11)	4.25 (4.83)
Physiological cost index, beats/minute	0.62 (0.27)	0.63 (0.46)	0.62 (0.36)
Predicted VO_2 max, mL/kg/minute	24.2 (6.0)	24.5 (5.2)	24.3 (5.6)

HOMA-IR, homeostatic model assessment of insulin resistance; IQR, interquartile range; SD, standard deviation

[a] Auto-immune disease requiring hematopoietic cell transplantation

[b] 20 allogeneic and 6 autologous transplants

[c] Expressed in terms of minutes of self-reported moderative physical activity, where time spent doing vigorous activity is weighted twice that of moderate activity

[d] Smokers were non-randomly assigned to the intervention arm; 9 other individuals were former smokers (4 intervention, 5 control)

TABLE 3.

Baseline and repeated measures mixed effects models for physical activity, dietary factors, quality of life, and health-related self-efficacy

Outcome	Intervention		Control		Difference (95% CI)	P-value
	Baseline (SD)	Mean change (95% CI)	Baseline (SD)	Mean change (95% CI)		
Physical activity						
Sedentary time, minutes/day	604.3 (97.2)	−4.1 (−36.8, 28.6)	585.7 (114.5)	−0.5 (−35.8, 34.8)	−3.6 (−51.3, 44.1)	0.88
Light PA, minutes/day	203.2 (57.2)	0.6 (−29.8, 30.9)	253.9 (94.2)	−0.8 (−33.5–32.0)	1.3 (−42.9, 45.5)	0.95
MVPA, minutes/day	18.9 (20.7)	3.5 (−3.4, 10.5)	20.2 (11.9)	1.2 (−6.4, 8.7)	2.4 (−7.8, 12.5)	0.65
Steps/day	4645 (2600)	711 (−251, 1673)	5848(2182)	260 (−779, 1299)	451 (−951, 1853)	0.53
Dietary factors						
Daily % added sugar	10.4 (3.9)	−0.8 (−2.2, 0.5)	9.4 (5.1)	0.1 (−1.5, 1.6)	−0.9 (−3.0, 1.1)	0.39
Daily % saturated fat	11.5 (2.0)	−0.3 (−1.5, 0.9)	12.6 (2.1)	−0.8 (−2.2, 0.6)	0.5 (−1.4, 2.3)	0.60
Sodium, mg/day	3633 (1500)	−832 (−1421, −243)	3383 (1197)	−279 (−937, 379)	−553 (−1435, 329)	0.22
HEI-2015	65.9 (6.0)	1.6 (−1.5, 4.6)	65.0 (8.6)	0.6 (−2.8, 4.0)	1.0 (−3.6, 5.6)	0.67
Quality of life, t-score						
Physical health	47.2 (5.4)	2.7 (0.7, 4.6)	49.7 (6.0)	1.8 (−0.3, 3.8)	0.9 (−1.9, 3.7)	0.52
Mental health	43.3 (7.9)	4.2 (1.5, 6.9)	49.0 (5.5)	1.8 (−1.1, 4.8)	2.4 (−1.6, 6.4)	0.24
Health-related self-efficacy, t-score	46.7 (10.5)	6.6 (2.1, 11.1)	52.3 (10.7)	2.2 (−2.8, 7.1)	4.4 (−2.3, 11.1)	0.20

CI, confidence intervals; HEI-2015, Health Eating Index-2015; MVPA, moderate-vigorous physical activity; SD, standard deviation

TABLE 4.

Qualitative interview results (n=10)

Selected Themes	Representative quotations
Positive sentiment	
Increased awareness	I didn't even realize that I was at risk for heart stuff because of [what] I've been through. And so, I think it was great to be made aware of that.
Lifestyle change	I'm trying to be more active than I was before, I'm trying to really watch, monitor, my health, trying to get better, knowing that there is some heart related issues with what I went through now. I have on my own been tracking everything I eat because I noticed I'd think about it more, then I would eat better when I was doing that.
Facilitators	
Altruism	Any way we can help further the cause of cancer research is good.
Improving own health	Seeing kind of where my fitness level was at after all the treatments and if there's things I can be doing to make my lifestyle healthier.
Study materials and information	I think it was very straight forward and there was an ability to ask questions if you needed more information.
Feedback & motivation from intervention	I would give like 4 out of 5 stars, because I feel like it does a great job obviously of tracking your daily habits and things like that. When you track everything it kind of gives you a scorecard on how you're doing, so then I would try to figure out what it would take to get some of the numbers higher. Because you realize that there's other people that went through the same things that you went through when you were sick.
Barriers	
Action plan goals not always helpful	I did not find the phone sessions particularly helpful. I did like the fact that we made some commitments to a certain amount of exercise on a weekly basis, but I don't know that they affected or changed my behavior much.
Incorporating feedback into daily life	Between my work and activities and kids, I didn't have the time… it was a very time-consuming piece where I kind of failed on keeping up with it.
Difficulty with apps	[Healthwatch360] seemed to be more geared to somebody that ate a lot of fast food or processed food….It was a little bit harder to find generic meals you might make at home and, and find a close equivalent to that on the app. After a couple of months I was just kind of bored with it and tired of wearing it.
Remembering to use apps	I had a really hard time of remembering… I would go, like a week… forget all about it.
Proposals for improvement	
More frequent check-ins	Follow-up at an earlier time, especially when you're not progressing… would have been more beneficial Maybe more telephone… just have a quick 10-minute check-in at least once a month.
More training on apps	If you had an interviewer sit down and go over all the functions… show them how to use it on their phone… I think you'd get people using it more.