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A Videoconference Physical Activity Intervention for Colorectal Cancer Survivors: A Pilot Randomized Controlled Trial

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Abstract

Physical activity (PA) after a colorectal cancer (CRC) diagnosis can improve physical function and quality of life and is associated with decreased mortality rates and longer disease-free survival. The accelerated use of videoconference technology during and following the COVID-19 pandemic offers an opportunity to explore the potential of a virtually supervised intervention to help survivors of CRC increase PA. A two-arm single blind pilot randomized

controlled trial of individuals who had completed treatment for CRC within the previous five-years (NCT03781154, 12/19/2018). The 12-week intervention consisted of circuit-based, combined aerobic and resistance exercise, twice per week for approximately one-hour per session, and five social cognitive theory-based PA behavior change discussion sessions. All intervention components were delivered in real-time via Zoom. Feasibility and acceptability were assessed, and the effects of the intervention were explored for the outcomes of PA (activPAL™ accelerometers and self-report), social cognitive theory constructs (barriers self-efficacy and outcome expectations), and physical fitness (submaximal aerobic capacity, upper and lower body muscular strength and endurance). Twenty-nine eligible individuals (55.2% women, *Mean* = 61 ± 11 years old, *Mean* = 22.0 ± 15.1 months since diagnosis) were randomized to the videoconference PA intervention (*n* = 15) or a PA education control (*n* = 14). A total of *N* = 25 completed the study for a retention rate of 86.7% in the intervention arm and 85.7% in the control. Adherence to intervention components was >86%. The intervention was highly acceptable with ≥90% responding "yes" or "definitely yes" that they enjoyed participating. Trends suggested that intervention participants had greater improvements in accelerometer measured steps per day, daily minutes of light PA, sedentary time, and aerobic fitness. There was no change in social cognitive theory constructs, and muscular strength and endurance improved in both the intervention and control. A 12-week videoconference PA intervention was feasible and acceptable among survivors of CRC, and the greatest magnitude of difference for intervention effects was observed for light PA and sedentary time. A fully powered trial is needed to determine efficacy of the intervention for increasing PA and physical functioning.

Keywords
Videoconference; physical activity; intervention; cancer survivor; colorectal cancer

1. Introduction

Colorectal cancer (CRC) is the third most common cancer in both men and women in the United States with over 100,000 new cases diagnosed in 2023 [1, 2]. Physical activity (PA) after a colorectal cancer diagnosis can improve physical function and quality of life [3-5], and is associated with decreased mortality rates and longer disease-free survival [6-8]. Unfortunately, survivors of CRC report some of the lowest levels of PA of any cancer survivor group [9, 10], and a recent study found survivors of CRC were sedentary, on average, 8-9 hours per day [11]. Therefore, efforts to increase PA in survivors of CRC present an enormous opportunity to improve cancer control and survivorship outcomes.

Two previous systematic reviews have summarized the effects of PA interventions to date for survivors of CRC [12, 13]. A review by Mbous et al. included 10 randomized controlled trials (RCTs), and found that overall, theory-based interventions increased moderate to vigorous PA (MVPA) among survivors of CRC, with a small effect size (*d* = 0.26) [12]. Jung et al. quantitatively synthesized PA data from three studies, and found that only one reported significant increases in PA levels in the intervention group compared to a control [13]. Taken together, findings from these reviews

suggest that the development of intervention strategies that elicit larger, more clinically meaningful increases in PA are warranted.

The majority of the interventions identified in both reviews were either home-based with remote-support (e.g., telephone calls, asynchronous videos, or print materials), or mHealth (i.e., app or text messaging) [12, 13], and across both reviews, only four studies included a supervised and/or structured PA component [14-17]. In addition, a recent meta-analysis found no effect of remote and unsupervised exercise interventions for improving PA among Survivors of CRC [18]. Thus, despite the scalability and accessibility benefits of home-based or remote-delivered interventions, PA interventions for survivors of CRC may need additional, more intensive components such as a supervised PA or exercise component.

Including a supervised PA or exercise component may have important potential benefits for increasing PA among survivors of CRC given what is known to date regarding successful behavior change techniques (BCTs) used in PA interventions for survivors of CRC. The review by Mbous et al. conducted a subgroup analysis of the effects of the BCTs included in the PA interventions, and found that in terms of effect size, two of the top three BCTs were behavioral practice and instruction on how to perform the behavior - BCTs that may be more effectively delivered in a supervised, synchronous (i.e., real-time) setting [12].

The accelerated use of videoconference technology during the COVID-19 pandemic offers an opportunity to explore the potential effects of a "synchronous, virtually supervised" delivery modality of a PA intervention for survivors of CRC. PA interventions utilizing videoconference technology may be able to overcome the scalability limitations (i.e., proximity/travel distance) of face-to-face supervised interventions, while retaining the important BCTs of behavioral practice and instruction on how to perform the behavior. The feasibility and effects of interventions delivered using videoconferencing among survivors of cancer have recently emerged [19], with several studies demonstrating promising results regarding feasibility and improvements in physical function [20-24]. However, only three previous studies in survivors of cancer with a virtually supervised PA/exercise component have measured changes in PA [24-26], only one has utilized a theoretical framework for PA behavior change [26], and none have targeted survivors of CRC.

Based on the low levels of PA and the important potential benefits of PA on physical and psychosocial outcomes for survivors of CRC, there is a critical need to explore alternative intervention strategies to help survivors of CRC increase PA. The purpose of this pilot study was to evaluate the feasibility and acceptability of a videoconference PA intervention in a sample of insufficiently active survivors of CRC. Additionally, we explored preliminary effects of the intervention on PA, social cognitive theory constructs, and physical fitness outcomes (e.g., aerobic fitness, muscular strength and endurance).

2. Materials and Methods

2.1 Participants, Enrollment, and Randomization

This study was a pilot, randomized controlled trial (RCT), which took place at the University of Colorado Anschutz Medical Campus, and Colorado State University. The University of Colorado Institutional Review Board (IRB#18-2436) approved this study. Informed consent was obtained from all individual participants included in this study, and study data were collected and managed using REDCap electronic data capture tools hosted at the University of Colorado [27].

The target population for this pilot RCT was individuals with non-metastatic colon or rectal cancer who had completed curative therapy within the previous five years. To be eligible, subjects had to meet the following inclusion criteria: fluent in English, have access to a computer or phone with internet and a camera, stated willingness to be randomized and attend in-person pre-/post-study visits at one of the two study sites, aged 40 years or older at time of diagnosis, histologically confirmed cancer of the colon or rectum (stages II-IV) if treated with curative intent, completed resection or other surgery 3-60 months prior to enrollment, received chemotherapy and/or radiation therapy within the previous year with at least 1 cycle of intended chemotherapy completed, and no plans for additional chemotherapy or radiation therapy. Exclusion criteria were evidence of metastatic disease, self-reported existing participation in ≥150 minutes per week of at least moderate intensity PA, pregnant or planning to become pregnant, and known contraindications for exercise or not able to safely participate in exercise, as identified by the Physical Activity Readiness Questionnaire (PARQ+) [28]. Potentially eligible participants were identified through several methods: (1) electronic medical records at the University of Colorado Cancer Center (healthdatacompass.org), and mailed letters followed by a phone call from a study staff member, (2) cancer clinic staff identified potentially eligible participants and referred them to the study coordinator, (3) study flyers sent to local and national colorectal cancer survivor support organizations, (4) study information posted websites such as the University of Colorado Cancer Center Community Outreach, and colorectal cancer organizations (e.g., fightcolorectal.org), and (5) approved study advertisements posted on the study team's social media platforms. Recruitment took place from February 2021 - July 2022.

The study coordinator confirmed eligibility and reviewed informed consent via telephone before consent was obtained electronically. Eligible participants were scheduled for an in-person baseline assessment at one of the two study locations, based on their preference. After completing the baseline assessment, participants were randomized 1:1 to the intervention or control group stratified by sex, in blocks of 10 using a computer-generated sequence [29]. The sequence was concealed from the study coordinator who assigned participants to intervention arm, and study staff conducting baseline and post-intervention assessments were blinded to group assignment.

Participants randomized to the intervention were provided study materials which included: a Polar M200 Heart Rate Monitor and chest strap (Polar H10 Heart Monitor, Kempele, Finland), a set of five resistance bands with tension weight equal to 5-25 lbs (Odoland©, New York, NY) along with a door mount, handles and ankle straps, a 10 or 15 lb kettlebell, an exercise mat, an inflatable exercise ball, study branded t-shirt and water bottle, and a workbook to guide discussion sessions. Prior to the first exercise session, participants met with the study coordinator 1:1 via Zoom. This meeting consisted of an introduction to Zoom technology features, review and set up of exercise equipment and an opportunity to answer any questions about what to expect for exercise sessions.

2.2 Intervention Description

The intervention was informed by social cognitive theory [30, 31], a theoretical framework that has been utilized in previously successful PA interventions for survivors of cancer [32-34]. The intervention consisted of exercise and discussion sessions, all delivered via Zoom videoconferencing (i.e., in real-time/live) to allow for the BCTs of behavioral practice and instruction on how to perform the behavior [35], which align well with constructs of the social cognitive theory (i.e., self-efficacy).

Exercise sessions were held twice per week and lasted approximately one hour. Exercise sessions were held live on Zoom, led by two study staff; an American College of Sports Medicine (ACSM) certified exercise physiologist with specialized training in exercise oncology [36], and a graduate student with a bachelor's degree in exercise science. Sessions consisted of a 5-minute warm-up, followed by four mini-circuits consisting of two resistance exercises and two aerobic exercises (Table S1). Suggested exercise intensity during these sessions was 40-70% of Heart Rate Reserve or RPE of 11-14 on a 6-20 scale [37], with instructions to start at the lower end of this range and progressively increase intensity as tolerated. Exercise sessions finished with a cool-down and light stretching for all major muscle groups, also led by the instructor. Participants were encouraged to exercise independently 1-3 times per week, at an intensity similar to supervised sessions. Independent exercise frequency, type, and modality was self-selected by participants.

To encourage PA behavior change, five discussion sessions were held live on Zoom following exercise session in weeks 1, 4, 7, 9 and 12 and lasted approximately 30-45 minutes each. Discussion sessions operationalized additional BCTs [35], which were guided by the Social Cognitive Theoretical framework [30, 31] and aimed to increase PA both during and following completion of the intervention. Participants were encouraged to achieve the exercise guidelines for cancer survivors [38], and progress to achieving the USDHHS PA guidelines [39]. The same exercise session personnel facilitated discussion sessions using a standardized fidelity checklist, while participants completed activities with a bound, printed program workbook. BCTs and discussion topics are outlined in Table S2.

2.2.1 Control Arm

After completing the baseline assessment and randomization, the control participants received information describing PA recommendations for cancer survivors from the American Cancer Society [40], via a printed mailed copy, or an emailed pdf. At the end of the study control participants were offered complimentary registration in an existing videoconference-delivered cancer-exercise program [41].

2.3 Measures

2.3.1 Feasibility and Acceptability

We assessed feasibility of the intervention through evaluation of completion of assessments conducted at the baseline and 12-week post-intervention study visits, adherence to exercise and discussion sessions, and attrition (proportion of participants who completed the 12-week post-intervention study visit). In line with previous videoconference exercise interventions in survivors of cancer [21-23], we considered the intervention feasible if we were able to achieve ≥85% assessment completion, ≥80% adherence and ≤20% attrition in the intervention arm. We assessed acceptability of the intervention with an investigator developed satisfaction questionnaire (Table S3). In addition, safety was assessed by recording adverse events according to NCI CTCAE (v5.0).

2.3.2 Physical Activity

PA was measured using the activPAL™ accelerometer (PAL Technologies, Glasgow, Scotland). The activPAL™ quantifies free-living sedentary and ambulatory activities, has previously been used in cancer survivors [42], and has been validated as one of the most accurate wearable activity monitors [43]. The activPAL is a small device worn on the thigh that uses information about static and dynamic acceleration to (1) distinguish body posture as sitting/lying, standing, and stepping and (2) estimate energy expenditure (expressed as metabolic equivalents [METs]). Participants wore the activPAL for seven consecutive days, 24 hours per day immediately following the baseline and post-intervention study visits. Participants were asked to record time of activPAL removal and sleep/wake up times. Data were downloaded using the activPAL software (version 7.2.38; PAL Technologies) and summarized using the activPAL processing package in R statistical software [44]. A valid day of data collection was defined as at least 10 hours of wear time and a valid observation period required at least 4 valid days with at least one of those days being a weekend day. Invalid days were excluded from analyses. Sedentary behavior was defined as waking behavior performed in the seated or lying position. MVPA was defined as walking behavior of at least 75 steps per minute and at least 1-minute in duration. Light intensity activity was defined as all waking behavior not in the seated or lying position and not meeting the threshold to be classified as MVPA [45]. Each variable was summed between all valid days and divided by number of valid days to calculate average daily values.

PA was also self-reported using the International Physical Activity Questionnaire (IPAQ) short form (https://sites.google.com/site/theipaq/). The IPAQ-short provides self-reported PA data regarding the frequency and duration of walking, moderate, vigorous and total PA in the previous seven days. Duration and frequency of walking, moderate, vigorous, and total PA were reported and are used to calculate metabolic equivalent of task (MET) minutes per week (days × time × MET values) for each category, and total PA MET minutes per week was calculated as the sum of walking, moderate, and vigorous PA MET minutes per week. Given the non-normal distribution of energy expenditure in many populations, the IPAQ guidelines for data processing suggest that these data are presented as median rather than mean MET-minutes (Guidelines for Data Processing and Analysis of the International Physical Activity Questionnaire (IPAQ) - Short Form Version 2.0). The IPAQ has been tested for reliability and validity in several different populations with acceptable measurement properties comparable to other established self-reports [46].

2.3.3 Social Cognitive Theory Constructs

The Barriers Specific Self-Efficacy Scale (BARSE) was used to examine perceived capability to exercise in the face of commonly identified barriers to exercise participation [47]. The BARSE is a 13-item questionnaire, and for each item, participants indicate their confidence to exercise on a 100-point percentage scale comprised of 10-point increments, ranging from 0% (not at all confident) to 100% (highly confident). Total score is calculated by summing the confidence ratings and dividing by the total number of items in the scale, resulting in a maximum possible self-efficacy score of 100. Previous studies have demonstrated acceptable internal consistency, reliability and validity of this measure [47].

The Multidimensional Outcome Expectations for Exercise Scale (MOEES) was used to examine the physical, social, and self-evaluative outcome expectations for exercise/PA [48]. The MOEES is a 15-item questionnaire, and for each item, participants indicate the degree to which they agree with

each statement (e.g., "Exercise will increase my muscle strength") on a scale of 1 (strongly disagree) to 5 (strongly agree). In addition to the already established physical, social, and self-evaluative dimensions, three questions were added to form a “cancer’ dimension [(1) “Exercise will reduce cancer risk”; (2) “Exercise will lower my risk of mortality from cancer”; (3) “Exercise will help with the negative side effects of cancer”]. Preliminary reliability analyses were conducted using Chronbach’s α (0.784), and a principal axis factor analysis was conducted on the 3 items, with one factor extracted (factor loadings ranged 0.697-0.803). The Kaiser-Meyer-Olin measure verified the sampling adequacy for this analysis (KMO = 0.703). MOEES dimensions were scored by summing the numerical rating for each question and dividing by the number of items in that dimension. Scores range from 1-5, with higher scores indicating of higher levels of outcome expectations for exercise.

2.3.4 Physical Fitness

Aerobic fitness was assessed with a submaximal, graded exercise test on a motorized, calibrated treadmill. Participants began walking at 3 miles per hour at a 0% grade. Every three minutes the grade was increased by 2.5%. Participants continued until they reached 70% of heart rate reserve (HRR), or symptom limitation (dyspnea and/or fatigue) [49, 50]. Aerobic fitness was quantified by the estimated volume of oxygen consumed (VO_2) achieved at the final stage of the test, calculated using the following equation [VO_2 (ml/kg/min) = (3.5 mL/kg/min) + (m/min × 0.1) + (grade [fraction] × m/min × 1.8) [50]. Muscular strength was assessed by 10-repetition maximum (RM) plate loaded seated bench press and leg press [51]. Strength was quantified by the estimated 1-RM of chest and leg press using a validated equation (100*weight/(101.3 - 2.67123*reps) [52]. Muscular endurance was assessed by the sit to stand and arm curl tests [53]. This is the number of full stands from a chair, and the number of bicep curls (holding a hand weight of 5lbs) that can be completed in 30 seconds.

2.4 Data Analysis

The primary analysis of this pilot study assessed the feasibility and acceptability of the intervention, and secondary analyses compared the intervention with the control arm on self-reported and accelerometer-measured MVPA, social cognitive theory constructs, and physical fitness. To assess feasibility and acceptability, recruitment, retention, intervention adherence, and degree of program satisfaction were calculated. Baseline comparisons between participants in the intervention versus control group were performed using chi-squared, Fisher’s exact tests, and independent samples t-tests, with significance set at $p < 0.05$. Descriptive statistics (means, standard deviations and medians) were calculated at each time point and mean or median differences and percent change in outcomes from baseline to 12-week post-intervention were calculated to explore magnitude of change. Effect size (Cohen’s *d*) was calculated using the means and standard deviations of the baseline and post-intervention values [Cohen's $d = M_1 - M_2/s_{pooled}$ where $s_{pooled} = \sqrt{[(s_1^2 + s_2^2)/2]}$. This pilot study was not powered to detect statistically significant differences in outcomes or the effectiveness of the intervention, thus inferential statistics were not performed. All statistical analyses were conducted in SPSS 26.0 (IBM SPSS Statistics, Armonk, NY). Sample size determination was based on determining feasibility and resources available to conduct the study [54].

3. Results

3.1 Feasibility and Acceptability

Twenty-nine eligible participants were randomized (*n* = 15 intervention, *n* = 14 control), out of n = 49 screened to be eligible (59.1% enrollment rate). Across both arms, *N* = 25 participants completed the study, with a retention rate of 86.7% (13/15) in the intervention arm and 85.7% (12/14) in the control arm. Flow through the study, and reasons for drop out/withdrawal are shown in Figure 1.

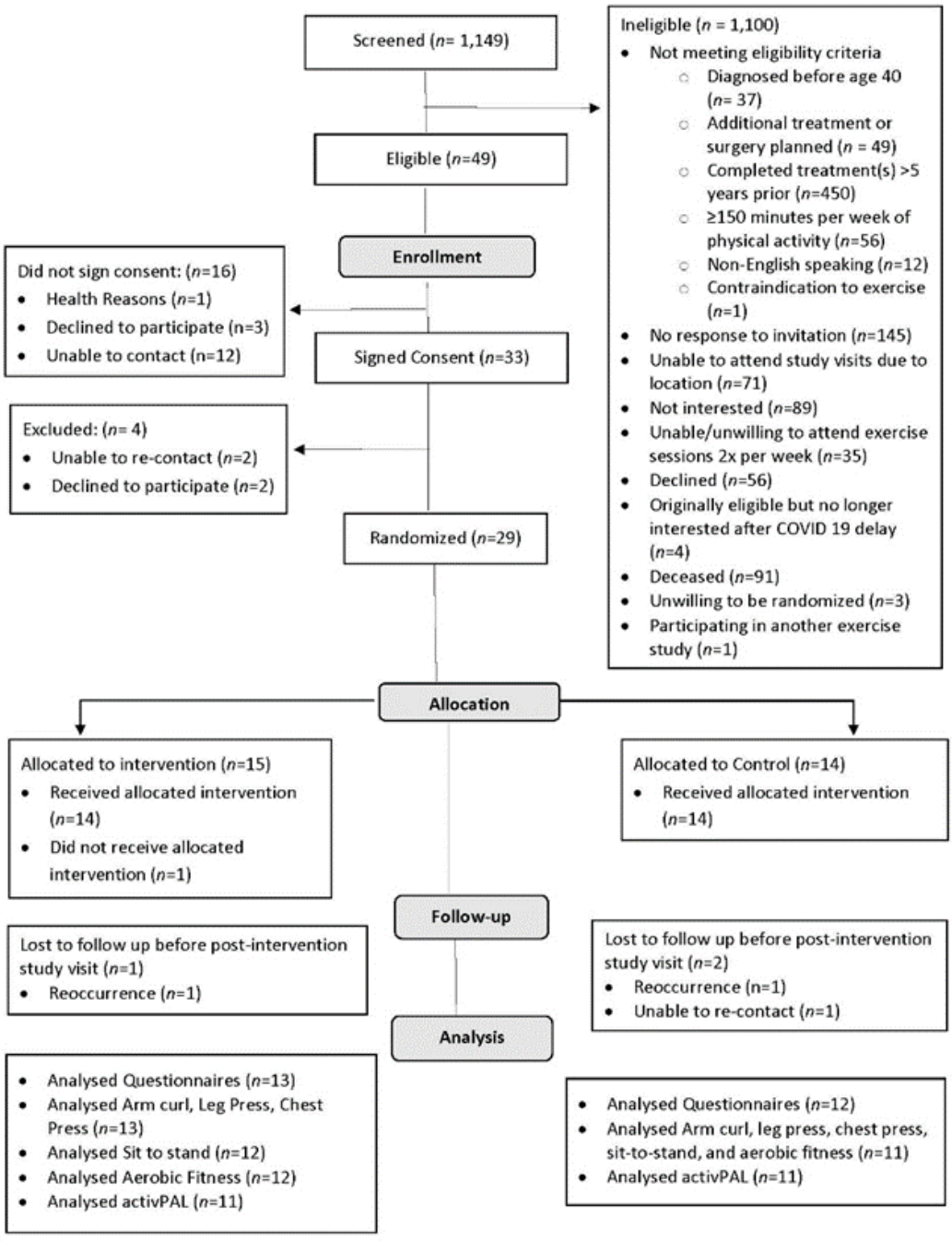

Figure 1 CONSORT Flow Diagram.

Characteristics of intervention and control participants are presented in Table 1.

Table 1 Characteristics of *N* = 29 colorectal cancer survivors enrolled in a pilot trial of a videoconference physical activity intervention.

	Total (*N* = 29)	Intervention (*N* = 15)	Control (*N* = 14)
Age (years)	61 ± 11	59 ± 11	63 ± 12
Body Mass Index (kg/m^2)	29.1 ± 5.6	28.7 ± 4.8	29.4 ± 6.5
Sex			
Male	13 (44.8)	6 (40)	7 (50)
Female	16 (55.2)	9 (60)	7 (50)
Race			
White	29 (100)	15 (100)	14 (100)
Ethnicity			
Hispanic or Latino	3 (10.3)	2 (13.3)	1 (7.1)
Education			
<4 year college degree	12 (41.3)	8 (53.3)	4 (28.6)
≥4 year college degree	17 (58.6)	7 (46.7)	10 (71.4)
Annual Family Income[a]			
<$50,000	3 (12.0)	2 (15.4)	1 (8.3)
≥$50,000	22 (88.0)	11 (84.6)	11(91.7)
Employment Status[a]			
Working full or part time	15 (53.6)	8 (53.3)	7 (53.9)
Not working	13 (46.4)	7 (46.7)	6 (46.1)
Cancer Site			
Colon	20 (69.0)	10 (66.7)	10 (71.4)
Rectum	5 (17.2)	4 (26.7)	1 (7.1)
Colon and Rectum	4 (13.8)	1 (6.7)	3 (21.4)
Tumor Stage[b]			
II	9 (31.0)	7 (46.7)	2 (15.4)
III	17 (58.6)	8 (53.3)	9 (69.2)
IV	2 (6.9)	0	2 (15.4)
Time since diagnosis (months)	22.0 ± 15.1	19.8 ± 12.1	24.3 ± 18.0

Data are presented as the mean ± SD for continuous variables and frequency (%) for categorical variables. For significance testing, all p-values were >0.10. Characteristics were compared using independent samples t-tests and chi-squared (or Fisher's exact) tests where appropriate. [a] *sample* does not equal *N* = 29 because participants selected "prefer not to answer this question". [b] *sample* does not equal *N* = 29 because stage could not be confirmed for one participant.

Participants were enrolled in six waves or "cohorts", with 2-4 participants in each intervention cohort. There were no statistically significant differences in demographic characteristics between intervention and control participants at baseline. Assessments at the baseline and 12-week post intervention study visits were feasible, with 99.6% of questionnaires, and 97.8% of physical fitness assessments completed at baseline, and 100% of questionnaires and 94% of physical assessments

completed at post intervention. Intervention participants attended an average of 20.6 ± 4.0 exercise sessions (out of 24 possible), and 4.85 ± 0.56 discussion sessions (out of 5 possible) for an overall adherence rate of 85.8% (*n* = 11/13 ≥ 75%) and 97.0% (*n* = 12/13 100%), respectively. Two adverse events were reported by intervention participants. These were both skin irritation attributed to the clear plastic bandage used to affix the activPAL accelerometer. One adverse event was reported by a control group participant, a hip fracture, which was not attributed to the study.

Participants reported that the intervention was highly acceptable. Intervention participants (*n* = 12, 92.3%) completed the post-intervention satisfaction survey, and ≥90% of participants responded "yes" or "definitely yes" that they "enjoyed participating in the intervention", "felt physically stronger", "felt they could better perform daily activities", "felt the staff and group environment provided a sense of community and support", "would recommend this program to a fellow cancer patient/survivor", "found the discussion sessions useful", and "have the knowledge and skills to exercise safely and effectively on their own". The median and IQR of all program satisfaction items along with responses to three open ended questions are shown in Table S3.

3.2 Physical Activity, Social Cognitive Theory Constructs, and Physical Fitness

Physical activity means and standard deviations or median and interquartile range, and changes from baseline to post-intervention are shown in Table 2.

Table 2 Physical Activity from Baseline to Post-Intervention.

Accelerometer Measured						
	Intervention (*n* = 11)			Control (*n* = 11)		
	Baseline	Post	Change	Baseline	Post	Change
	Mean ± SD	*Mean ± SD*	*Δ, (range), effect size*	*Mean ± SD*	*Mean ± SD*	*Δ, (range), effect size*
Moderate and vigorous PA (minutes per day)	12.7 ± 7.5	16.6 ± 9.2	3.9 (-3.1-17.6), *d* = 0.46	24.1 ± 18.3	28.2 ± 30.1	4.1 (-26.9-48.7), *d* = 0.16
Light PA (minutes per day)	316.6 ± 91.7	345.2 ± 103.0	28.6 (-170.3-129.5), *d* = 0.29	285.9 ± 92.8	282.2 ± 73.8	-3.7 (-127.2-64.6), *d* = -0.04
Sedentary time (mins per day)	612.9 ± 92.7	559.1 ± 78.4	-53.8 (-172.6-90.3), *d* = 0.63	610.3 ± 106.7	634.8 ± 83.2	24.6 (-135.3-172.7), *d* = -0.26
Steps per day	5966.4 ± 2132.3	7531.8 ± 2192.6	1565.3 (-877.1-4541.7), *d* = 0.72	7979.3 ± 2881.0	8117.0 ± 3692.9	137.7 (-4856.8-7056.0), *d* = 0.04
Self-Reported						
	Intervention (*n* = 13)			Control (*n* = 12)		
	Baseline	Post	Change	Baseline	Post	Change
	Median (IQR)	*Median (IQR)*	*Median Δ (range)*	*Median (IQR)*	*Median (IQR)*	*Median Δ (range)*
Vigorous PA (MET-minutes per week)	0 (0-360)	0 (0-2040)	0 (-2880-4800)	0 (0-960)	0 (0-2100)	0 (-2400-7200)
Moderate PA (MET-minutes per week)	0 (0-720)	1440 (240-1980)	720 (-1440-10,800)	150 (0-2790)	840 (30-1380)	120 (-4200-2880)
Walking (MET-minutes per week)	297 (49.5-1089)	396 (148.5-915.75)	0 (-3366-2178)	1277 (429-2301.75)	2079 (1608.75-3081.38)	891 (-1039.5-4158)

Total PA (MET-minutes per week)	1188 (99-1939)	1638 (529-6654)	678 (-2952-15,192)	2803 (807.25-5881.5)	3467.5 (2079-5692.5)	1327 (-4917-11,268)

activPAL reasons for missing data: n = 1 skin reaction, n = 1 forgot to wear device.

Participants in the intervention showed an increase in accelerometer measured light PA, and a decrease in sedentary time, whereas the control group decreased light PA and increased sedentary time. Intervention participants showed a greater increase in accelerometer measured daily steps, and similar increases in MVPA as the control group (3.9 vs. 4.1 minutes per day). For self-reported PA, intervention participants reported a greater increase in moderate PA, but smaller increases in walking and total PA than the control group. At post-intervention, both the intervention and control group reported lower self-efficacy for overcoming barriers to exercise compared to baseline, and physical, self-evaluative, and cancer outcome expectations for exercise increased slightly more in the intervention group. All metrics of physical fitness improved in both the intervention and control group to a similar extent, with the exception of aerobic fitness which increased among intervention participants but declined slightly among control participants. Means, standard deviations, and changes from baseline to post-intervention for social cognitive theory constructs and physical fitness outcomes are shown in Tables 3 and 4, respectively.

Table 3 Social Cognitive Theory Constructs.

	Intervention (*n* = 13)			Control (*n* = 12)		
	Baseline	Post	Change	Baseline	Post	Change
	Mean ± SD	*Mean ± SD*	*Δ, (range), effect size*	*Mean ± SD*	*Mean ± SD*	*Δ, (range), effect size*
Barriers Self-Efficacy[a]	67.6 ± 20.6	54.4 ± 24.0	-13.2 (-61.5-17.7), *d* = -0.59	60.1 ± 19.2	56.3 ± 16.2	-4.62 (-30-+39.2), *d* = -0.21
MOEES - Physical Outcome Expectations	4.4 ± 0.53	4.6 ± 0.31	0.24 (-0.67-1), *d* = 0.46	4.6 ± 0.33	4.6 ± 0.46	0.03 (-1.0-0.67), *d* = 0
MOEES - Social outcome expectations	3.3 ± 0.70	3.1 ± 0.85	0.11 (-1.75-1), *d* = -0.26	3.5 ± 0.69	3.3 ± 0.47	0.19 (-2.0-0.75), *d* = -0.34
MOEES - self-evaluative outcome expectations	4.2 ± 0.54	4.3 ± 0.63	0.12 (-0.80-1), *d* = 0.17	4.3 ± 0.51	4.3 ± 0.69	0.02 (-0.80-1), *d* = 0
MOEES - Cancer outcome expectations	3.8 ± 0.83	4.2 ± 0.69	0.41 (-0.33-1.33), *d* = 0.52	3.8 ± 0.87	3.9 ± 0.89	0.14 (-1.7-1.0), *d* = 0.11

[a] *Barriers* Self-Efficacy = n = 12 intervention, n = 11 control. Missing due to participant skipping over this questionnaire at the post-intervention study.

Table 4 Physical Fitness.

	Intervention (*n* = 13)			Control (*n* = 11)		
	Baseline	Post	Change	Baseline	Post	Change
	Mean ± SD	*Mean ± SD*	*Δ (range), effect size*	*Mean ± SD*	*Mean ± SD*	*Δ (range), effect size*
Sit-to-stand (repetitions)[a]	14.0 ± 5.2	14.9 ± 2.9	0.92 (-12-8), *d* = 0.21	14.6 ± 5.5	16.0 ± 7.2	1.4 (-5-7), *d* = 0.22
Arm curl (repetitions)	16.5 ± 4.4	18.4 ± 4.0	1.9 (-4-9), *d* = 0.45	19.3 ± 6.8	20.6 ± 6.2	1.4 (-3-6), *d* = 0.20
Leg Press Estimated 1-RM (lbs)	197.4 ± 65.1	236.9 ± 109.2	39.5 (-26.7-180), *d* = 0.44	216.4 ± 146.8	235.2 ± 148.7	18.8 (-26.7-53.3), *d* = 0.13
Chest Press Estimated 1-RM (lbs)	48.9 ± 30.9	63.3 ± 46.7	14.4 (-6.7-53.3), *d* = 0.37	50.1 ± 33.5	65.5 ± 43.6	15.3 (0-+53.3), *d* = 0.39

Estimated submaximal VO_2 (ml/kg/min)	18.8 ± 5.6	22.1 ± 5.2	3.3 (-3.6-18.1), *d* = 0.61	24.9 ± 7.0	24.2 ± 6.9	-0.72 (-7.2-3.6), *d* = -0.1

[a] *Sit* to stand n = 12 for intervention; VO_2/test time n = 12 for intervention, n = 10 for control. HRR = Heart Rate Reserve; RM = Repetition Maximum.

4. Discussion

This pilot RCT examined the feasibility and acceptability of a videoconference-delivered PA intervention for survivors of CRC, and explored preliminary effects of the intervention on PA, social cognitive theory constructs and physical fitness outcomes. This study demonstrated feasibility and acceptability of the intervention, and light intensity PA tended to increase to a greater extent in the intervention vs. control. Feasibility and acceptability outcomes and changes in all outcome measures will be discussed in further detail below.

In terms of feasibility and acceptability, adherence and retention were high, similar to previous PA interventions among survivors of CRC with a supervised exercise/PA component [14, 15, 55] and other videoconference exercise interventions in survivors of breast and prostate cancer [21-23], and the vast majority of participants reported they were highly satisfied with their experience in the intervention. However, also similar to previous PA interventions in survivors of CRC, enrollment was challenging. Given that the current study was constrained by location due to in-person pre-/post-intervention study visits, the number enrolled out of those screened for eligibility (2%) may be expected, given a recent text-messaging PA intervention study for survivors of CRC, which was able to recruit nationally, had only 10% of those screened enroll in the study [56]. Enrollment rate in the current study (59.1%) was also slightly higher than some other PA interventions with a supervised exercise/PA component; Lee et al. enrolled 23/186 (12.4%) that met eligibility criteria, and Van Waart et al. enrolled 23/63 (36.5%) who were referred to the study [14, 55]. The largest ongoing PA intervention study in survivors of CRC, Courneya et al. randomized 273/323 (84.5%), however this trial involved 42 different centers, which equates to an enrollment of only 6-7 participants per site between 2009 and 2014 [15]. Thus, future studies to better understand barriers to recruitment and enrollment of survivors of CRC to PA intervention studies are warranted.

We were not statistically powered to test effectiveness of the intervention, however trends suggested improvements in several PA, and all physical fitness-related outcomes. Accelerometer measured PA showed greater increases in light PA and steps in the intervention compared to the control group, decreases in sedentary time in the intervention vs. increased sedentary time in the control group, and similar increases in MVPA. Self-reported PA demonstrated high variability, with no change in vigorous PA in the intervention or control, and larger increases in moderate PA in the intervention, but greater increases in walking and total PA in the control. All physical fitness outcomes improved in both the intervention and control group, with the exception of aerobic fitness, which only increased in the intervention group. Taken together, these findings are largely congruent with the largest PA intervention with a structured exercise component conducted to date among survivors of CRC (N = 200) [15]. Courneya et al. found that although intervention participants showed larger increases in self-reported MVPA and metrics of physical functioning, the health education control group also saw improvements as well [15]. This suggests that (a) increase in PA among control groups in exercise oncology interventions is common [57], signifying that cancer survivors who enroll in these studies are highly motivated to exercise and may change their behavior despite the request to maintain their current or usual activity pattern [58], and (b) this increase in PA among control participants may lead to a decrease of power to detect a significant intervention effect, eliciting the need for larger sample sizes and longer intervention duration. This raises the questions of (1) how do we engage survivors of CRC in PA intervention who are *not* highly motivated to exercise (i.e., those who need the most support)? and (2) If educational health materials are

effective tools to increase PA in cancer survivors [59], how lasting are these effects, and thus, are the effects of more intensive behavioral interventions only apparent after the initial 'adoption period' (i.e., indicating a need for studies with longitudinal follow-up)?

One unique finding from this study was the differences in changes in light PA and sedentary time between the intervention and control group. There were limited changes in MVPA at post-intervention, and intervention participants MVPA levels were still below the recommended PA guidelines. These findings suggest that intervention participants may have been replacing sedentary time with light PA, and perhaps, light PA may be a more viable behavioral target than MVPA for inactive survivors of CRC. To our knowledge, only one previous intervention in survivors of CRC has examined accelerometer-measured changes in sedentary time and found modest reductions [11]. Although evidence is accumulating to support the notion that higher levels of light PA (independent of MVPA), is associated with lower mortality risk and improved health outcomes in the general population [60], relationships between sedentary time, light PA, and health outcomes specific to survivors of CRC is only just emerging. One cross-sectional study found that sedentary time was associated with poorer quality of life outcomes in survivors of CRC [61], whereas another found no significant associations of sedentary time with quality of life, physical function or fatigue among survivors of CRC [3]. In terms of light PA, one cross-sectional study found that light PA was independently associated with higher physical functioning among survivors of CRC [62], and a longitudinal study found that higher levels of light PA were associated with better quality of life and less fatigue in survivors of CRC [63]. However, both of these studies utilized self-reported assessments of light PA, suggesting that additional prospective and intervention studies using objective measures are necessary to understand how behavioral interventions can target light PA, and how changes in sedentary time and light PA may contribute to improved health outcomes among survivors of CRC.

Another novel outcome from this study was incorporating measures of change in social cognitive theory constructs. Trends showed a decrease in confidence to overcome barriers to exercise in both the intervention and control group, and no change in outcome expectations with the exception of cancer-related outcome expectations. Only one previous PA intervention in survivors of CRC has utilized a social cognitive theory framework [64]. This home-based PA intervention resulted in increases in self-reported weekly minutes of PA but did not measure any social cognitive theory constructs. A seminal social cognitive theory-based PA intervention among breast cancer survivors by Rogers et al. is one of few studies that measured changes in social cognitive theory constructs [65]. This study found large increases in task self-efficacy and reductions in perceived barriers interference, modest reductions in negative outcome expectations, and no effect of the intervention on positive outcome expectations. However, this study utilized different measure of outcome expectations and measured task self-efficacy rather than barriers self-efficacy. Thus, future studies of PA interventions in survivors of cancer should compare the sensitivity of these various measures of social cognitive theory constructs. Finally, this study included an internally developed scale to measured cancer-specific outcome expectations (i.e., reduce risk, mortality, and treatment side effects), and we postulate that the content delivered in Discussion Session 3 (Table S2), contributed to trends for increases in this subscale following the intervention. To our knowledge only one previous study has explored exercise outcome expectations as they related to cancer-specific outcomes among survivors of breast cancer, and found low levels of agreement that exercise may mitigate late and long-term cancer and treatment effects [66]. Thus, additional studies

in survivors of cancer are needed to explore the perception that PA or exercise may positively impact cancer-related outcomes, determine the extent to which these positive expectations are associated with PA levels, and whether providing empirically supported information about these benefits and/or participating in an exercise intervention or program impacts these beliefs.

4.1 Strengths and Limitations

A strength of this study was rigorous pilot testing of a videoconference-delivered PA intervention in cancer survivors. Given the rapid transition of many face-to-face PA and exercise interventions to videoconferencing during the COVID-19 pandemic, there is a need to move toward solidifying the feasibility, safety, and effectiveness of this delivery modality among survivors of cancer. Further, in terms of a novel contribution to the existing literature, no previous PA interventions in survivors of CRC with a supervised, structured exercise component have used objective measures of PA, nor utilized social cognitive theory as a theoretical framework [12, 13]. Finally, another strength of this study was enrollment of a relatively inactive sample of participants (based on baseline levels of objectively measured MVPA) compared to recent PA interventions in survivors of CRC [56, 67]. Limitations of the current study included a sample size which was not adequately powered to examine between group differences in outcomes, a highly motivated sample as evidenced by increases in PA among the control group, and lack of diversity with all participants self-reporting as white and middle to high income.

5. Conclusions and Future Directions

There are many lessons learned during this pilot study that can inform a larger trial and the next lines of inquiry. First, to increase sample size, reach of the intervention (i.e., reduce constraints based on geographic location), and potentially diversity, a larger trial could conduct all assessments remotely. Our study team has previously established the feasibility of collecting activPAL data via mailing methods [68], and recent studies have established the reliability and validity of physical function assessments conducted remotely among cancer survivors [69]. Future studies should also consider the pros and cons of enrollment in waves or "cohorts" vs. rolling enrollment. Although cohorts are ideal for group cohesion and delivery of sequential behavior change discussion sessions (i.e., sessions were ordered and built upon content in the previous session), rolling enrollment may help increase the ease and speed of accrual. Future videoconference PA intervention studies should examine effects on psychosocial and/or patient reported outcomes (i.e., quality of life, fatigue), as well as the sustainability of PA behavior change. Given that videoconferencing is able to include the important BCTs of behavioral practice and instruction on how to perform the behavior but is also delivered in participant's own environment, there is a need to examine how this intervention modality might contribute differently to PA maintenance compared to traditional face-to-face or asynchronous remote delivery modalities. Finally, preliminary results from this study suggest that the largest between group differences were in sedentary time and light PA. Since few studies in survivors of CRC have used objective measures of PA to capture these outcomes, more studies are needed to examine how changes in these behaviors relate to clinically relevant outcomes (e.g., tumor biomarkers or patient reported outcomes).

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Author Contributions

HJL conceived of the research idea. HJL, ADB, MGC and WAM contributed to the study design. HJL and WAM oversaw regulatory compliance. HJL completed the data analyses and wrote the first draft of the article. MCH and ELG collected and managed the data. KL managed and processed activPAL data. All authors aided in interpreting results and revising the manuscript. All authors provided critical feedback on the manuscript and approved the final version that was submitted for publication.

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Competing Interests

The authors have no financial or other conflicts of interest to disclose.

Additional Materials

1. Table S1: Exercise Session Example.
2. Table S2: Discussion session Topics and Activities.
3. Table S3a: Acceptability based on quantitative responses to post-intervention survey (*N* = 12).
4. Table S3b: Acceptability based on open-ended responses to post-intervention survey (*N* = 12).

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