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ORIGINAL ARTICLE

Improvements in strength and agility measures of functional fitness following a telehealth-delivered home-based exercise intervention in endometrial cancer survivors

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Abstract

Purpose Endometrial cancer is strongly linked to obesity and inactivity; however, increased physical activity has important benefits even in the absence of weight loss. Resistance (strength) training can deliver these benefits; yet few women participate in resistance exercise. The purpose of this study was to describe both physiological and functional changes following a home-based strength training intervention.

Methods Forty post-treatment endometrial cancer survivors within 5 years of diagnosis were enrolled in a pilot randomized trial, comparing twice-weekly home-based strength exercise to wait list control. Participants conducted the exercises twice per week for 10 supervised weeks with 5 weeks of follow-up. Measures included DXA-measured lean mass, functional fitness assessments, blood biomarkers, and quality of life outcomes.

Results On average, participants were 60.9 years old (SD = 8.7) with BMI of 39.9 kg/m^2 (SD = 15.2). At baseline, participants had 51.2% (SD = 6.0) body fat, which was not different between groups. Improvements were seen in the 30-s chair sit to stand (d = .99), the 30-s arm curl (d = .91), and the 8-ft up-and-go test (d = .63). No changes were measured for HbA1c or C-reactive protein. No changes were observed for flexibility (chair sit and reach, back scratch tests), 6-min walk test, maximum handgrip test, anxiety, depression, fatigue, or self-efficacy for exercise.

Conclusions Home-based muscle-strengthening exercise led to favorable and clinically relevant improvements in 3 of 7 physical function assessments. Physical function, body composition, blood biomarkers, and patient-reported outcomes were feasible to measure. These fitness improvements were observed over a relatively short time frame of 10 weeks.

Keywords Resistance exercise · Strength · Quality of life · Intervention

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Introduction

There are more than 624,000 endometrial cancer survivors living in the USA, projected to increase to over 740,000 in 2030 [1]. The 5-year survival rate for early-stage disease is very good (81% for stage IB and 90% for 1A [2]). However, endometrial cancer survivors have a high rate of obesity and medical comorbidities that can compromise physical functioning and quality of life [3]. Physical activity can improve health-related quality of life [4], yet endometrial cancer survivors tend to exhibit sedentary behavior and have low physical activity participation rates [5]. Current physical activity guidelines recommend that cancer survivors achieve 150 min of moderate-intensity activity, avoid inactivity, and perform muscle-strengthening activities at least 2 days per week [6]. These recommendations reflect strong evidence

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that resistance exercise improves anxiety, depressive symptoms, fatigue, health-related quality of life, and perceived physical function [7]. Furthermore, higher levels of physical activity were associated with lower all-cause mortality, even after adjusting for body mass index [8]. Unfortunately, only 12% of gynecologic cancer survivors are sufficiently active to meet physical activity recommendations, and only 8% of survivors meet the strengthening exercise recommendation [9]. Resistance exercise, also known as strength training or muscle-strengthening activity, should be performed at least twice per week for all major muscle groups [10]. The American College of Sports Medicine provides specific recommendations for beginners of 2–4 sets per exercise of 8–12 repetitions at 60–70% of estimated maximal strength [10].

Strength training offers unique metabolic and physiologic benefits that are critical in this population. Metabolic disruptions are common in endometrial cancer survivors, including dysregulation of the glucose system manifesting as prediabetes or type 2 diabetes mellitus [11]. Strength training can independently upregulate the GLUT-4 cell receptors that bring glucose into the cell, thereby improving systemic glucose regulation, in addition to the other metabolic improvements of exercise [12]. Resistance exercise has additional benefits for bone mineral density, glucose tolerance and control, and insulin sensitivity [13]. While both aerobic and resistance training increase energy expenditure and improve cardiovascular fitness, resistance exercise confers additional metabolic improvements by increasing lean tissue content. This change in tissue proportion increases basal metabolic rate while also yielding higher vascularity of muscle tissue and higher mitochondrial density [13]. These changes translate to improved function and performance in activities of daily living [14].

Previous lifestyle interventions have used resistance exercise in endometrial cancer survivors, but they often include weight loss as the end point or combine resistance exercise with other lifestyle changes [15, 16]. While weight loss has positive health consequences, maintaining weight loss over the long term is challenging, and a high proportion of individuals will regain the lost body fat but are less likely to regain muscle. Focusing on strengthening the muscles is especially important for post-menopausal endometrial cancer survivors who are already at increased risk for sarcopenic obesity [17]. Furthermore, not all survivors are ready for, or interested in, programs that involve dieting or weight loss. Fortunately, even in the absence of weight loss, physical activity may be a productive behavioral target in endometrial cancer survivors. A previous work has shown that higher levels of physical activity were associated with lower all-cause mortality, even after adjusting for body mass index [8].

This study used a home-based approach to strength training for endometrial cancer survivors to capitalize on the well-established benefits of resistance training while reducing barriers to resistance training, including geographic or distance to recreational facilities. The primary outcomes of this randomized controlled pilot were feasibility, safety, and acceptability of home-based strength training. The purpose of this study was to measure the direction and magnitude of changes in study outcomes for the intervention. To explore the different improvements in physical function and quality of life following strengthening exercise, study outcomes included body composition (lean muscle mass and adipose tissues) measured via dual-energy x-ray absorptiometry (DXA), blood biomarkers of inflammation and glucose control, functional fitness performance, and patient-reported outcomes of anxiety, depression, fatigue, and self-efficacy for exercise and overall quality of life. We hypothesized that a 10-week at-home resistance exercise intervention in endometrial cancer survivors would result in favorable short-term changes in study measures compared to a wait list control group. Changes in study measures are important to quantify for planning future investigations of medium- and long-term health outcomes.

Methods

This was a pilot randomized controlled trial that tested a 10-week home-based resistance training program versus wait list control. The study was conducted in Madison, WI and was approved by the University of Wisconsin-Madison's Health Sciences Institutional Review Board (Protocol #2018–0953) and by the Carbone Comprehensive Cancer Center's Protocol Review and Monitoring Committee (Protocol UW18013). Prior to enrollment of the first participant, the study was registered at clinicaltrials.gov (NCT03722030). Written informed consent was obtained from all participants.

Participants

Participants were 40 endometrial cancer survivors who met the following eligibility criteria: age 18–74, diagnosis of non-metastatic (stages I–III) type I endometrial cancer within the past 5 years, and at least 10 weeks post-completion of primary treatment. Women were ineligible if they were currently undergoing active treatment and were excluded if they had recurrent or metastatic disease, were already participating in resistance exercise at least 2 days per week, or were unwilling to complete study measures. Additionally, women completed the Physical Activity Readiness Questionnaire (PAR-Q) [18] over the phone and were excluded if they endorsed one or more items, indicating a potential safety risk with exercise. Participants were

recruited from the UW Carbone Comprehensive Cancer Center from October 2018 until October 2019.

Study components

All participants attended an assessment visit at week 1 (baseline) and at week 10 (post-intervention). At these visits, participants had their physical measures taken (described below). Each participant was assigned with 1:1 probability to either the intervention or wait list control group. The wait list control group received print materials about healthy survivorship from the American Cancer Society [19], and received exercise materials (manual and YouTube access) and resources (dumbbells, resistance bands) at week 10 visit.

Intervention group

This group had one additional in-person visit to learn the exercises, receive the materials, and obtain personalized coaching, completed within 1 week of randomization. Post visit, participants began twice-weekly sessions at home. The exercise program was a full-body routine of 8 exercises to be completed on non-consecutive days at least twice weekly [6, 20]. These exercises targeted all 5 major muscle groups: chest, back, arms (deltoids, biceps, triceps), abs, legs and buttocks. Each participant received a set of resistance bands with handles (Black Mountain Products, Elkhorn, WI) and one set of two dumbbells (options of 5-, 6-, 8-, 10-, and 12-lb sets), which was proportional to the participant's body size and baseline strength performance [21]. Participants also received access to a private YouTube channel for viewing exercise demonstrations and a printed exercise manual. Briefly, adherence to the exercise prescription was high with 75% of the intervention group completing at least two sessions per week. On average, participants reported 19.2 sessions over the 10-week period out of the expected 20 sessions total [22].

Assessments

Participants had two in-person assessments at baseline (entry into study) and week 10 (final study visit). These measures included the following:

Anthropometrics All anthropometric measures were taken at baseline and at follow-up. Weight was measured in kilograms, to the nearest tenth kilogram. Height was measured twice to the nearest tenth centimeter at baseline, with the two measurements averaged for accuracy. Waist circumference was measured at the natural waist (the narrowest part of the abdomen) and the hip circumference was measured at the widest part of the hips and buttocks, both measured in centimeters. Dual-energy x-ray absorptiometry (DXA, GE Healthcare) full-body scans provided estimates of lean muscle mass and body fat percentages, and bone mineral content/density.

Functional fitness battery The functional fitness test (FFT) is a battery of seven tests measuring strength, flexibility, fitness, body composition, and agility. This battery focuses on assessing abilities necessary for daily function, and these tests reflect salient movements for an older population, including rising from a chair unassisted, navigating a floor obstruction with ease, and upper limb mobility. The battery has high test–retest reliability and is suitable for tracking within-person changes [23]. The functional fitness test battery includes the following seven standardized assessments from the Rikli et al. older adult fitness testing protocol: the 30-s chair stand, the 30-s arm curl, the 6-min walk test, the chair sit and reach, the 8-ft up-and-go, the back scratch test, and finally the handgrip strength via a handgrip dynamometer [23].

Blood biomarkers To measure the potential impact of the intervention on systemic inflammation and glucose control, blood biomarkers were collected at baseline and week 10 following a standardized dried blood spot collection procedure. A sanitized finger was lanced, and four drops of finger blood were collected on a protein saver card (Whatman 903 protein saver cards), left to dry, and then were refrigerated until analyzed. Glycosylated hemoglobin and C-reactive protein, markers of glucose control and systemic inflammation, were measured from the samples which have been validated for measurement via dried blood [24]. Analyses were completed using ELISA kits from Invitrogen (Cat # KHA0031) for C-reactive protein, and from Biomatik (Cat. # EKC33865) for HBA1c [25]. Concentrations were calculated in https://www.elisaanalysis.com/ using 4-parameter logistic regression.

Patient-reported outcomes To measure the impact of the intervention on patient-reported measures of quality of life and overall mental well-being, participants completed questionnaires at baseline, week 5 (midway through intervention), and week 10 (post-intervention) via REDCap (Research Electronic Data Capture) electronic data capture tools hosted at the University of Wisconsin-Madison [26, 27]. *Endometrial-specific Quality of Life*: The endometrial cancer version of the Functional Assessment of Cancer Therapies (FACT-En) is a 43-item scale used to assess domains of physical, social/family, emotional, and functional well-being post-treatment [28]. Participants complete 5-item Likert-type scales rating topics central to well-being in the past 7 days, and results are standardized against a normal cancer population. *Self-efficacy for Exercise Scale*: The Self-efficacy for Exercise Scale (SEE) is a 9-item (rating 0–10)

survey to self-report feelings of efficacy specific to exercise demands, which has been validated against the physical and mental health scores on the RAND 12-Item Short Form Health Survey (SF-12). Aggregated scores range from 0 to 90, with higher scores indicating higher self-efficacy for exercise [29]. *Patient-Reported Outcome Measurement Information Systems (PROMIS)*: The National Institutes of Health–funded PROMIS measures are person-centered questionnaires on physical, mental, and social health, and have specific measures for the general population as well as for individuals with cancer. The PROMIS instruments are standardized at mean of 50 (standard deviation of 10) with higher scores indicating higher levels of the measured construct [30]. Anxiety [31], depression [31], and fatigue[31, 32] were each collected separately via 8-item short form questionnaires, with a 1–5 rating per item on survey, with a higher rating indicating a higher level of anxiety, distress, or fatigue.

Data analysis

As this was a pilot investigation, formal a priori sample size calculations were not used. Based on a review of the literature, a sample of 40 with 20 per arm was the minimum number of participants needed to obtain sufficient data for the primary outcome of feasibility [33, 34]. Analyses of study outcomes are primarily exploratory, focusing on the magnitude and directionality of outcomes [35]. Characteristics were reported using means and standard deviations for continuous variables, with frequencies and percentages for categorical variables. To measure the direction and magnitude of effects in the intervention group, Cohen's *d* was calculated for effect size estimation for study outcomes, and standardized change scores were calculated. The effect size is used to quantify the magnitude of intervention effect relative to the control condition, and the size of the effect is proportional to the relationship influence. To measure time and group by time changes for repeated measures outcomes for the intervention group, linear mixed effects models (PROC MIXED) were used to calculate point estimates and 95% confidence intervals. Corrections for multiple testing were not including following Rothman's guidance [36]. All analyses were conducted using SAS 9.4 (SAS; Cary, NC).

Results

Study population

Demographic and clinical variables of both the intervention and wait list control group are presented in Table 1. Mean age was 60.9 (SD = 8.7) years, and participants were 2.9 years since diagnosis on average. Mean BMI was 39.9 kg/m^2 (SD = 15.2), with half the sample having a BMI classified as type III obesity. Using the 2003 Urban Influence codes, 10 participants (25%) are from non-metro (rural) areas.

Body composition

Body composition results from DXA scans are presented in Table 2. At baseline, study participants had 51.2% (SD = 6.0) body fat, which was not different between groups. Body fat percentage for both groups showed a small decline over 10 weeks (loss of 0.4%, $d = 0.24$; Table 2) that was not statistically significant. Mean changes in lean muscle mass resulted in the intervention group gaining lean muscle mass (increase of 1.0 lb) while the control group lost lean mass (decrease of 0.7 lb), with a measured effect size of 0.11 for the intervention group. These changes were also not different between groups over time (Table 2).

Functional fitness

The pre- and post-intervention measures for both groups are presented in Table 2. Performance on all fitness tests did not differ between groups at baseline. Improvements in strength were observed for the intervention group with increases in the total number of repetitions in the 30-s arm curl ($d = 0.91$) and increases in total number of repetitions for the 30-s chair sit to stand ($d = 0.99$) (Table 2). No substantive changes were seen for flexibility (chair sit and reach and back scratch test), and for the 6-min walk test. Significant improvements were measured for the intervention arm for the 8-ft up-and-go test (speed improvement − 0.07 s, $p = 0.03$). Significant group by time effects were observed for the intervention group for the 30-s arm curl, the 30-s chair sit to stand, and the 8-ft up-and-go agility assessment (Table 2).

Blood biomarkers

Table 2 also shows the pre- to post-intervention measures of C-reactive protein and glycosylated hemoglobin (HbA1c), and for both biomarkers the mean change increased over the intervention period, which was not statistically significant. Moderate, but non-statistically significant, effect sizes were found for HbA1c (0.21) and C-reactive protein (0.24) (Table 2). The interaction term for the intervention group over time was not significant for either measure (Table 2).

Patient-reported outcomes

The repeated measures collected at baseline, week 5, and week 10 are presented in Table 3 which includes the estimates and confidence intervals for the influence of time as well as the group by time interaction for the intervention

Table 1 Baseline demographic characteristics for full sample, exercise intervention group, and wait list control

	Overall Mean (SD) or *n* (%)	Exercise intervention Mean (SD) or *n* (%)	Wait list control Mean (SD) or *n* (%)
N	40	20	20
Age in years	60.9 (8.7)	60.9 (9.6)	60.9 (8.0)
Married/partnered	28 (70%)	15 (75%)	13 (65%)
Education			
High school graduate or less	3 (7.5%)	1 (5.0%)	2 (10.0%)
Trade school/some college	13 (32.5%)	7 (35.0%)	6 (30.0%)
College graduate	14 (35.0%)	6 (30.0%)	8 (40.0%)
Post-graduate degree	10 (25.0%)	6 (30.0%)	4 (20.0%)
BMI (kg/m^2)	39.9 (15.2)	42.2 (19.5)	37.9 (8.6)
Healthy (BMI < 25)	2 (5%)	1 (5%)	1 (5%)
Overweight (25–29.9)	4 (10%)	1 (5%)	3 (15%)
Obese I (30–34.9)	8 (20%)	4 (20%)	4 (20%)
Obese II (35–39.9)	7 (17.5%)	5 (25%)	2 (10%)
Obese III (40 +)	19 (47.5%)	9 (45%)	10 (50%)
Percentage total body fat (DXA)	51.2% (6.0)	51.6% (5.0)	50.4% (6.8)
Baseline waist circumference (cm)	106.8 (16.0)	107.9 (16.9)	105.5 (15.2)
Baseline hip circumference (cm)	129.7 (18.7)	130.2 (18.4)	129.2 (19.4)
Waist-to-hip ratio	0.83 (.06)	0.82 (.04)	0.83 (.07)
Lowest risk[1]	18 (45%)	8 (47%)	10 (52.6%)
Middle risk	7 (17.5%)	4 (23.5%)	3 (15.8%)
Highest risk	11 (27.5%)	5 (29.4%)	6 (31.6%)
Tumor stage at diagnosis			
Stage I	33 (82.5%)	15 (75.0%)	18 (90.0%)
Stage II	2 (5.0%)	2 (10.0%)	0 (0.0%)
Stage III	5 (12.5%)	3 (15.0%)	2 (10.0%)
Treatment			
No treatment beyond surgery	30 (75%)	14 (70.0%)	16 (80.0%)
Radiation alone	3 (7.5%)	2 (10.0%)	1 (5.0%)
Chemotherapy alone	3 (7.5%)	0 (0.0%)	3 (15.0%)
Chemotherapy + radiation	4 (10.0%)	4 (20.0%)	0 (0.0%)
Time since diagnosis (years)	2.9 (1.2)	2.8 (1.2)	3.0 (1.3)
Time since surgery (years)	2.8 (1.3)	2.7 (1.4)	3.0 (1.3)

None of the comparisons between these group baseline characteristics were statistically significant

[1]Categories defined by the World Health Organization, lowest risk is ≤ 0.8, middle risk is 0.81–0.85, and highest risk is > 0.86 for women

group. At baseline, both groups were comparable and no different than a standardized cancer population. *PROMIS measures*: Significant changes in mean scores or effect sizes (*d*) were not observed over time for PROMIS measures of anxiety ($d = 0.18$), fatigue ($d = 0.06$), or depression ($d = 0.19$). The interaction term for the intervention group by time was not statistically significant. *Self-efficacy for exercise*: While self-efficacy for exercise was highest at baseline (intervention = 63.4 (SD = 20.4), control = 63.7 (SD = 19.7)), the effect size was not statistically significant ($d = 0.26$). There was evidence for an impact of change over time (change − 0.8, $p = 0.04$) but these were not specific to the intervention group as the group by time interaction term was not statistically significant (change 0.4, $p = 0.38$) (Table 3). *Functional Assessment of Cancer Therapies (FACT)*: The effect size for the overall instrument was 0.08 but there was a range for different subscales at the highest for social well-being ($d = 0.18$) and smallest for physical well-being ($d = 0.03$) (Table 3). There was evidence for an influence of time for the overall FACT scale (change − 4.5, $p < 0.001$), physical subscale (change − 0.5), functional subscale (change 6.8), and endometrial scales (change 9.2). These changes over time were not unique to the intervention group as the group by time interaction terms were not significant for any of the subscales.

Table 2 Pre and post study measures of body composition and functional fitness battery performance for exercise intervention and wait list control groups

	Intervention group mean (SD)			Control mean (SD)					
	Baseline	Week 10	Net Δ	Baseline	Week 10	Net Δ	Cohen's *d*	Group × time *β* (95% CI)	*p* value
Body comp									
Body fat %	51.6% (5.0)	50.6% (5.2)	−0.6 (0.9)	50.4% (6.8)	50.0% (7.2)	−0.3 (1.5)	.24	−0.0 (−0.1, 0.0)	.35
Fat percentile	93.3 (9.4)	91.8 (10.8)	−1.0 (2.7)	91.7 (12.0)	90.8 (13.2)	−0.7 (3.3)	.10	−0.0 (−0.2, 0.1)	.69
Total pounds muscle	105.3 (18.6)	104.2 (16.8)	1.0 (2.6)	104.1 (15.3)	102.0 (14.0)	−0.7 (3.3)	.11	0.1 (−0.1, 0.3)	.15
Fitness									
Arm curl (reps)	16.0 (3.1)	21.0 (5.7)	4.9 (3.7)	14.1 (3.1)	16.5 (3.8)	2.2 (2.0)	.91	0.4 (0.2, 0.6)	.0007
Sit/stand (reps)	12.1 (2.9)	15.4 (4.5)	3.3 (3.5)	10.7 (2.9)	11.2 (2.7)	0.3 (2.4)	.99	0.4 (0.2, 0.6)	.0003
Handgrip (kg)	22.0 (6.0)	22.5 (6.4)	0.7 (2.2)	21.8 (5.4)	21.2 (4.7)	−0.4 (2.1)	.14	0.1 (−0.0, 0.3)	.11
Sit and reach (in)	−1.2 (3.5)	−0.4 (3.1)	0.9 (2.3)	0.7 (4.3)	0.4 (2.9)	−0.5 (3.7)	.13	0.1 (−0.1, 0.2)	.60
Back scratch (in)	−8.0 (4.6)	−6.9 (4.1)	1.1 (1.7)	−5.1 (5.4)	−4.9 (4.9)	0.1 (4.1)	.32	0.0 (−0.2, 0.3)	.80
6-min walk (ft)	1549 (318)	1615 (358)	70.0 (89.3)	1571 (228)	1568 (349)	34.9 (114)	.34	4.0 (−3.5, 11.6)	.29
8-ft up/go (s)	6.6 (1.3)	5.9 (1.0)	−0.7 (0.9)	6.9 (1.4)	6.7 (1.2)	−0.1 (1.0)	.63	−0.1 (−0.1, −0.0)	.03
Blood biomarkers									
HbA1c (ng/mL)	7.3 (5.5)	12.3 (6.3)	4.7 (8.4)	6.4 (2.3)	9.1 (5.0)	3.2 (5.9)	.21	0.3 (−0.0, 0.7)	.06
CRP (ng/mL)	683.8 (255.7)	892.5 (611.1)	222.1 (538.3)	802.9 (568.)	810.2 (703.9)	108.6 (400.9)	.24	11.1 (−25.3, 47.5)	.36

Discussion

Endometrial cancer survivors who were randomized to a 10-week home-based strength training intervention demonstrated improved functional fitness. Pilot data indicated improvements in two strength assessments (30-s chair sit to stand and 30-s arm curl test) and for the 8-ft up-and-go agility measurement relative to the wait list control group. Our measured effect sizes for the strength assessments (chair sit to stand $d=0.99$, 30-s arm curl $d=0.91$) are large, and comparable to that found in a recent systematic review ($d=0.86$) [37]. Improvements in functional fitness metrics are especially promising given the relatively low dose of exercise delivered in this study. Moreover, these results have clinical relevance: The 8-ft up-and-go assessment is a predictor of fall risk in older adults [38]. Recent evidence indicates that reductions in function are key predictors in overall health decline and risk of mortality [39]. The improvements seen in strength are consistent with the exercise prescription calibrated to an intensity necessary to deliver strength benefits [10]. The pattern of results indicates that twice-weekly strength exercises did not uniformly improve fitness in the participants; rather, the benefits were specific to the intervention target of strength. Future investigations should consider the specificity of the intervention for desired targets, whether that be flexibility or other aspects of fitness.

Compared to an age- and sex-matched sample from the National Health and Nutrition Examination Survey (NHANES), this sample was, on average, in the 93rd percentile for body fat percentage [40]. The increase in lean muscle mass for the intervention group ($d=0.11$) is small in magnitude but relatively comparable with recent systematic reviews of resistance exercise in cancer survivors showing a similar moderate effect size of $d=0.28$ [37]. The 0.7 lb loss of lean muscle mass in the control group is consistent with findings that women lose about 1 kg of lean muscle mass per year after menopause [41]. Endometrial cancer survivors are at risk for sarcopenic obesity, which may be

Table 3 Repeated study measures for patient-reported outcomes at baseline, week 5, and week 10 for exercise intervention and wait list control

	Intervention group mean (SD)			Pre-post	Control mean (SD)			Pre-post	Cohen's *d*	Time *β* (95% CI)	Group × time *β*
	Baseline	Week 5	Week 10	Net Δ	Baseline	Week 5	Week 10	Net Δ			
Anxiety	46.6 (3.4)	48.2 (3.2)	46.4 (3.4)	−0.3 (6.7)	47.5 (3.3)	47.7 (3.1)	48.9 (2.9)	1.5 (6.6)	.18	0.2 (−0.1, 0.5)	−0.2 (−0.6, 0.2)
Fatigue	50.5 (8.9)	48.7 (8.7)	48.1 (2.9)	−2.5 (7.9)	50.9 (3.1)	48.7 (2.9)	48.8 (3.1)	−2.0 (9.3)	.06	−0.01 (−0.7, 0.7)	−0.0 (−0.4, 0.3)
Depression	46.4 (3.4)	44.1 (4.1)	44.6 (3.9)	−1.8 (5.0)	49.1 (2.9)	47.1 (3.4)	48.1 (3.4)	−0.8 (5.4)	.19	−0.03 (−0.3, 0.2)	−0.2 (−0.5, 0.1)
Self-efficacy	63.4 (20.4)	57.3 (19.0)	60.0 (21.3)	−3.4 (19.)	63.7 (19.7)	58.3 (20.3)	57.7 (22.9)	−6.0 (14.7)	.26	−0.8 (−1.5, −0. 1)[1]	0.4 (−0.5, 1.4)
FACT	146. (11.9)	146. (13.2)	146. (15.0)	−0.30 (14.)	141. (21.7)	142. (21.7)	140. (26.1)	0.6 (13.)	.17	−4.5 (-5.6, −3.6)[1]	0.2 (−0.9, 1.3)
Physical	24.4 (2.3)	24.5 (2.9)	24.8 (2.9)	0.4 (2.7)	24.0 (3.4)	23.9 (4.3)	24.5 (4.5)	0.5 (2.5)	.03	−0.5 (−0.7, −0.3)[1]	0.3 (−0.01, 0.5)
Social	22.3 (3.2)	22.4 (5.0)	22.3 (4.8)	−0.0 (3.6)	20.6 (6.5)	20.8 (6.0)	19.7 (7.6)	−0.9 (3.8)	.18	−0.1 (−0.3, 0.08)	−0.0 (−0.2, 0.2)
Emotional	21.1 (2.7)	21.4 (2.4)	20.8 (3.8)	−0.4 (3.3)	20.4 (3.3)	20.7 (3.3)	20.2 (3.4)	−0.1 (3.0)	.09	0.05 (−0.1, 0.2)	0.2 (−0.0, 0.4)
Functional	23.0 (2.6)	22.9 (3.2)	23.3 (3.5)	0.3 (2.8)	21.6 (5.0)	21.7 (5.3)	21.0 (6.3)	−0.5 (3.3)	.06	6.8 (5.5, 8.1)[1]	0.6 (−0.7, 1.8)
En[2] scale	55.0 (7.1)	54.6 (7.2)	55.0 (7.5)	−0.0 (5.1)	54.5 (7.1)	54.7 (5.0)	55.0 (7.0)	0.4 (5.8)	.07	9.2 (7.6, 10.9)[1]	0.6 (−1.1, 2.2)

[1]Represents statistical significance at alpha < .05

[2]Endometrial-specific subscale

accelerated in younger survivors who have menopausal onset following hysterectomy [2, 42], highlighting the promise for strength training interventions to preserve or increase lean muscle in endometrial cancer survivors. Improvements in lean muscle mass for cancer survivors also have beneficial metabolic implications and are linked to improved function [43]. While the changes seen are compelling, it is important to emphasize that lean muscle mass changes were not statistically significant, and it will be important to test effects with adequately powered samples. While no changes in muscle mass were observed, there were also no changes in measured blood biomarkers including glucose control and inflammation. The intervention may not have had sufficient duration or frequency to produce effects in these measures. Additionally, the blood samples were not collected in a fasted state since we completed all the measures (including the functional fitness testing) at one visit to reduce the number of times participants had to come in for study assessments. We also did not restrict any medication use, did not give any guidance, or collect any information about tobacco use, alcohol use, or dietary assessment in proximity to the blood collection. Any of these factors may be impacting the circulating measures of inflammation.

No significant group by time effects were seen for any of the patient-reported outcomes, with both groups showing similar changes in measures over time. It is important to note that both groups reported relatively normal baseline function on the symptom measures across the assessment points. While perhaps surprising, this can occur due to a response shift [44], whereby cancer survivors may change their frame of reference for optimal quality of life based on adverse experiences with treatment. The overall good baseline scores on these measures leave little room for an intervention to have much impact; future research might focus on areas of psychological or physical functions that are more impaired. It is also possible that intervention dose or duration of follow-up was insufficient for measurable change. Our findings stand in contrast to a systematic review that found significant improvements in quality of life measures with resistance exercise ($d = 0.25$) [37]. Results are more consistent with the most recent roundtable report from the American College of Sports Medicine, which indicated there was insufficient evidence to conclude that resistance exercise alone improves anxiety or depression in cancer survivors [7]. It is also important to note that the intervention did not add to negative symptom burden. In particular, fatigue, which can sometimes increase initially following a new exercise program [45], was stable for intervention participants.

Strengths of the study include the randomized design and the home-based approach which allows for greater reach and scalability for future work. This study also included a comprehensive measurement strategy to collect preliminary measures of the benefits of resistance

training physiologically (blood biomarkers of inflammation and blood glucose control) and systemically (body composition lean and fat mass), and for the individual herself based on her report (patient-reported outcomes) or her performance (functional fitness). Body composition was measured via DXA, providing precise estimates for both fat and lean muscle mass. Limitations include a lack of racial diversity in this sample (98% non-Hispanic white). Future work should include larger, more diverse samples of survivors. Our sample did include 25% rural residents, providing some evidence for use in rural populations, who may especially benefit from a home-based approach. The biomarker assessments were not done in a fasted state, nor were controlled with respect to medications, alcohol, caffeine, or diet, which is another limitation. Also, the assays used for the glycosylated hemoglobin analysis led to a quantitative result that was not easily converted into a readily clinically interpretable percentage. Finally, it is important to note that we are unable to distinguish the most effective and beneficial components of the intervention.

In conclusion, the pilot data collected from this home-based strength training intervention indicated improvements in two functional strength and one agility assessment, with very preliminary evidence suggestive of improvements in body composition. There was no evidence of intervention effects for anxiety, fatigue, depression, quality of life, or self-efficacy. Resistance exercise was made feasible by providing participants with resources including the materials (dumbbells, bands), knowledge (instruction, exercise manual, exercise videos), and support (study coordinator) through a supervised 10-week long intervention. Future work should consider a longer follow-up period to assess whether improvements are sustained and whether participants adhere to exercise protocols. Overall, these results show promise for the utility of resistance exercise to improve health and physical functioning in endometrial cancer survivors.

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Data availability Due to the nature of this research, participants of this study did not agree for their data to be shared publicly, so supporting data is not available.

Code availability N/A

Declarations

Ethics approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. This study was approved by the University of Wisconsin-Madison's Health Sciences Institutional Review Board (Protocol #2018–0953) and by the Carbone Comprehensive Cancer Center's Protocol Review and Monitoring Committee (Protocol UW18013). Prior to enrollment of the first participant, the study was registered at clinicaltrials.gov (NCT03722030).

Consent to participate Written informed consent was obtained from all individual participants included in the study.

Consent for publication N/A

Conflict of interest The authors declare no competing interests.

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