Supportive Care in Cancer (2021) 29:6305–6314
https://doi.org/10.1007/s00520-021-06209-6

ORIGINAL ARTICLE

Paired exercise has superior effects on psychosocial health compared to individual exercise in female cancer patients

Paulette M. Yamada[1] · Cheri Teranishi-Hashimoto[2] · Erin O. Bantum[3]

Received: 4 January 2021 / Accepted: 7 April 2021 / Published online: 15 April 2021

Abstract

Purpose Exercise improves the quality of life (QOL) in cancer patients recovering from treatment. Since group exercise fosters cohesion, we sought to determine if paired exercise would have similar, positive effects. An experiential study design was used to compare the effect of exercise (12 weeks) on psychosocial health in paired versus individually trained cancer patients.

Methods Female cancer patients (n = 28) who completed cancer treatment were placed into either the singly trained or paired group. Groups were matched for cardiorespiratory fitness (peak oxygen consumption, single: 24.1 ± 7.4, pair: 24.8 ± 6.3 ml/kg/min) and age (single: 58 ± 12, pair: 58 ± 9 years). Patients participated in 36, 90-min exercise sessions in accordance with exercise recommendations. QOL (Functional Assessment of Cancer Therapy-General, FACT-G), depressive, fatigue, and insomnia symptoms were measured before, midway, and after the intervention. Fitness was measured pre- and post-intervention. Participants did not meet prior to the intervention. Two-way ANOVAs and multiple comparisons tests were used to detect differences ($p < 0.05$).

Results Emotional well-being and total FACT-G scores were significantly improved in the paired but not individually trained patients. Depressive symptoms were significantly improved at mid- and final time points in the paired group. Paired patients reported significant improvements in insomnia symptoms from pre- to mid-intervention. Depressive and insomnia symptoms in the individually trained group were unchanged. A significant main effect of group was detected in fatigue scores in patients who were not chronically tired at baseline ($F(1, 12) = 6.318$, $p = 0.0272$). Both groups exhibited similar improvements in fitness.

Conclusion Paired exercisers had greater benefits in QOL, emotional well-being, and insomnia and depressive symptoms compared to individual exercisers.

Keywords Social cohesion · Depression · Insomnia · Quality of life · Fatigue

Introduction

Cancer diagnosis and treatment worsens psychosocial health, and this leads to poor prognosis [1] and negatively impacts long-term survival [2, 3]. Fatigue affects 70–80% of all cancer patients during treatment, and 30% of patients report fatigue 10 years after treatment [4]. The diagnosis of cancer itself causes emotional distress, with women reporting higher rates of anxiety and depression when compared to men [5]. Improving psychosocial health is an essential component of survivorship care. Singly trained cancer patients who engage in supervised exercise programs consisting of aerobic and resistance training report better outcomes on fatigue [6], depression [7], and quality of life (QOL) [8]. Over half of the studies included in a meta-analysis were conducted with breast cancer survivors, and showed that exercise during and after treatment is related to significant decreases in fatigue; this finding was observed in multiple cancer types [9].

Social support has been found to play a strong role in adjustment for cancer survivors. Social support was shown to have a significant, positive correlation with both QOL and the efficacy of psychosocial interventions [10], and to have positive influences on post-traumatic symptoms and recovery

✉ Paulette M. Yamada
pyamada@hawaii.edu

1 Department of Kinesiology and Rehabilitative Science, University of Hawaii, Manoa, 1337 Lower Campus Road PE/A 231, Honolulu, HI 96822, USA

2 Rehabilitation Hospital of the Pacific, Honolulu, HI, USA

3 Population Sciences in the Pacific Program, University of Hawaii Cancer Center, Honolulu, HI, USA

[11]. There is substantial evidence suggesting that physical activity after diagnosis is associated with a 34% lower risk of breast cancer–specific mortality [12]. A comprehensive study examining social networks of over 9000 socially isolated, breast cancer survivors had higher incidence of recurrence and mortality [13]. Additionally, group exercise has been shown to foster cohesion [14] and improve overall QOL [15]. For these reasons, we questioned if exercising in pairs would retain positive, group cohesion effects. Thus, the purpose of the study was to compare the effect of a 12-week exercise program on psychosocial health in cancer patients who exercised in pairs versus those who received one-on-one exercise training. Since improvements in physical fitness have the capacity to improve the ability to complete activities of daily living, which directly impacts psychological outlook, a second purpose was to evaluate the effect of training type on fitness gains.

Methods

Design and procedures

Twenty-eight female patients who completed cancer treatment were enrolled (mean age ± SD: 58 ± 11 years, breast cancer, $n = 26$, ovarian cancer, $n = 1$, lymphoma cancer, $n = 1$). Patients were recruited through a state-wide referral network which comprised oncologists, radiologists, and surgeons. All participants received exercise clearance from their medical provider and medical histories were provided. Inclusion criteria included being female, having been diagnosed with cancer, having completed clinical cancer treatments at least 3 months previously, being ambulatory, over the age of 18 years, received exercise clearance from their oncology provider, literacy in English, and ability to attend exercise sessions 3 times per week for 12 weeks during business hours. Patients were excluded from participating in the study if they did not meet all inclusion criteria. All exercise testing and exercise sessions took place in an outpatient physical therapy clinic. Prior to participation, patients provided their verbal and written consent. Research activities were approved by the Institutional Review Board in accordance with the Helsinki Declaration (#2018-00167). This trial was not registered. All data were collected prior to the COVID-19 pandemic.

Self-reported measures of QOL (Functional Assessment of Cancer Therapy-General, FACT-G), fatigue (Brief Fatigue Inventory, BFI), insomnia (Insomnia Severity Index), and depression (Patient Health Questionnarire-9, PHQ) were reported at pre- (baseline), mid- (6-weeks), and final (12 weeks) time points. Pre- and post-intervention evaluations assessed each component of fitness (cardiovascular capacity, muscular strength and endurance, body composition, and flexibility). The results of the assessments were used to create exercise prescriptions for each participant.

Patients exercised in pairs ($n = 14$) or individually ($n = 14$). The participants did not meet prior to the study, and they kept the same partner for the duration of the study. Groups were matched for cardiorespiratory fitness as measured with maximal oxygen consumption (VO_2peak, single: 24.1 ± 7.4 ml/kg/min; pair: 24.8 ± 6.3 ml/kg/min) and age (single: 58 ± 12 years, pair: 58 ± 9 years). Singly trained patients had completed treatment for breast cancer ($n = 12$), ovarian cancer ($n = 1$), or lymphoma ($n = 1$). Paired patients had completed treatment for breast cancer ($n = 14$).

An exercise specialist knowledgeable in cancer exercise rehabilitation principles led participants through personalized exercise sessions in pairs or in a one-on-one format. Exercise programs incorporated exercise training principles and followed recommendations for cancer patients [16–18]. Patients completed cardiovascular training at 40–60% of their heart rate (HR) reserve (30 min) and 5–7 resistance training exercises (40–60% of the subject's 1-repetition maximum, 1-RM, 30 min). Balance was trained alone or concurrently with resistance training, and flexibility was incorporated (15 min). Exercise intensity was verified with the rate of relative perceived exertion (RPE) and HR. Participants exercised at a workload corresponding to an intensity of 3–6 (on a scale of 0.5 to 10). Progressive overload was built into the program by pre-determining target cardiovascular and resistance training workloads at the beginning of the program. Exercises were not performed to volitional fatigue as intensity remained below maximal effort. At least 1 rest day was placed between training sessions.

The exercise specialist developed rapport and trust with his/her patients by providing encouragement and used patient input to plan exercises which would progress her toward personal fitness goals. Patients had the same specialist for the intervention; the interaction was comfortable, and in most instances, friendships developed. The specialist corrected exercise form and ensured the patient exercised at the targeted cardiovascular intensity (using HR reserve) and gauged resistance training intensity with RPE [18]. Cardiovascular exercises were chosen based upon the patients' preferences and available equipment, i.e., stationary bike, treadmills, Nu-steps, elliptical machines, rowers. If patients did not find these modes engaging, interval-like training was used for cardiorespiratory training. Paired patients exercised on machines in close proximity to each other. During resistance training in paired groups, camaraderie was encouraged by using partner-exercises and/or alternating work-rest bouts allowing one patient to encourage the other.

Flexible programming was employed because we aimed to help patients progress toward their goals, which enhanced their motivation (unpublished findings). As such, resistance training exercises were varied. Functional exercises were employed, mimicking activities of daily living, using pulley-weight systems, dumbbells, TheraBands, body weight exercises, and medicine balls. The exercises used to test 1-RMs were performed once every 2 weeks using pre-determined workloads. The number of repetitions and sets were varied to ensure both muscular strength and endurance were trained.

Dependent variables

Psychosocial measures

The FACT-G was used to assess QOL and it consists of 27 items which measures 4 dimensions of well-being: physical (7 items), social/family (7 items), emotional (6 items), and functional (7 items). The physical and emotional dimension scores were reversed; a higher total score reflects a high QOL. This survey is reliable, accurate, and sensitive to changes [19, 20].

The BFI is a 10-item survey which assesses the severity of fatigue and its impact on performance of daily activities. The first question assesses chronic fatigues as it asks if the patient has felt "unusually tired or fatigued in the past week." The remaining nine questions required the patient to score the level of fatigue or the impact of fatigue on general activity, mood, work, and relationships within a 24-h period. A higher tallied score indicates worsened acute fatigue symptoms [21].

The Insomnia Index is a validated instrument (7 items) that assesses the ability to fall sleep, stay asleep, and quality of sleep [22]. A total score of 0–7, 8–14, 15–21, and 22–28 is interpreted as no clinically significant insomnia, subthreshold insomnia, moderate severity clinical insomnia, and severe clinical insomnia, respectively.

The PHQ (10 items) assesses severity of depression and has good sensitivity, specificity, and accuracy in detecting symptoms of depression [23]. Patients report symptoms on a scale of 0 to 3, with 0 corresponding to limited disturbance and 3 relating to high disturbance. Total scores of 5–9, 10–14, 15–19, and > 20 indicate minimal symptoms, minor depression, moderate depression, and severe depression, respectively.

Physical fitness measures

Prior to physical fitness testing, resting vital measurements were used to verify that all subjects had normal blood pressure, oxygen saturation, and sinus rhythm. Body weight and body fat percentage was estimated using the sum of 3 skinfolds [16]. Cardiorespiratory endurance was measured using a treadmill test using a protocol specific for the cancer patient population [24] where final speed and grade were used to estimate VO_2peak [16]. The test was terminated upon volitional fatigue, the patient's request to stop or if contraindications to exercise were observed.

Muscular strength was assessed using 1-RM tests of 7 major muscle groups (chest press, latissimus dorsi pulldown, shoulder press, seated rhomboid row, leg press, leg extension, and leg curl), and in cases the 1-RM could not be achieved, a prediction equation was used to estimate 1-RM using the maximum weight lifted for 10 or fewer repetitions [25]. The chair squat test was used to measure lower body muscular endurance. The maximum number of squats performed up to 1 min or until fatigue was recorded. Hamstring flexibility was measured with the modified sit-and-reach test, and balance was measured with a single-leg stance.

Statistical analyses

Psychosocial parameters were analyzed with 2 × 3 ANOVAs (analysis of variance) with factors group (pair, single) and time (pre, mid, final). If psychosocial measures were available for 2 out of the 3 time points, it was used in mixed-model ANOVAs. BFI scores were further analyzed by separating data according to the patient's response to the first question which asks about feeling unusually fatigued. Data from participants who reported feeling unusually tired at baseline were analyzed separately from patients who reported not feeling unusually fatigued at baseline.

Physical fitness measures were analyzed with 2 × 2 ANOVAs with factors time (pre, final) and group (single, paired). Analysis of physical fitness measures was performed on complete sets which were collected at both time points (pre, final). For psychosocial and physical measures, Bonferroni's multiple comparisons tests were used to detect differences between groups. Significance was set at $p < 0.05$. Preliminary data and a priori power analyses indicated that 17–27 or 11–16 subjects would be needed to detect a large (0.80), or medium effect size (0.6, 95% probability, using paired samples) in FACT-G subscales and BFI and PHQ indices, respectively (SPSS version 26).

Results

Eleven individually trained and 12 paired patients completed the intervention (23 participants in total). Five patients did not complete the intervention because of illness or cancer reoccurrence (n = 3) or due to time conflicts (family emergency/work schedule, n = 2). Paired subjects whose partner was unable to attend their scheduled session exercised with the exercise leader to simulate paired activity (5.5% occurrence). Data contained in this report represent observations from patients who completed all 36 sessions. Figure 1 and Table 1 illustrate psychosocial outcomes.

Emotional well-being and total FACT-G scores were significantly different between paired and singly trained patients. Multiple comparisons tests showed that paired patients had

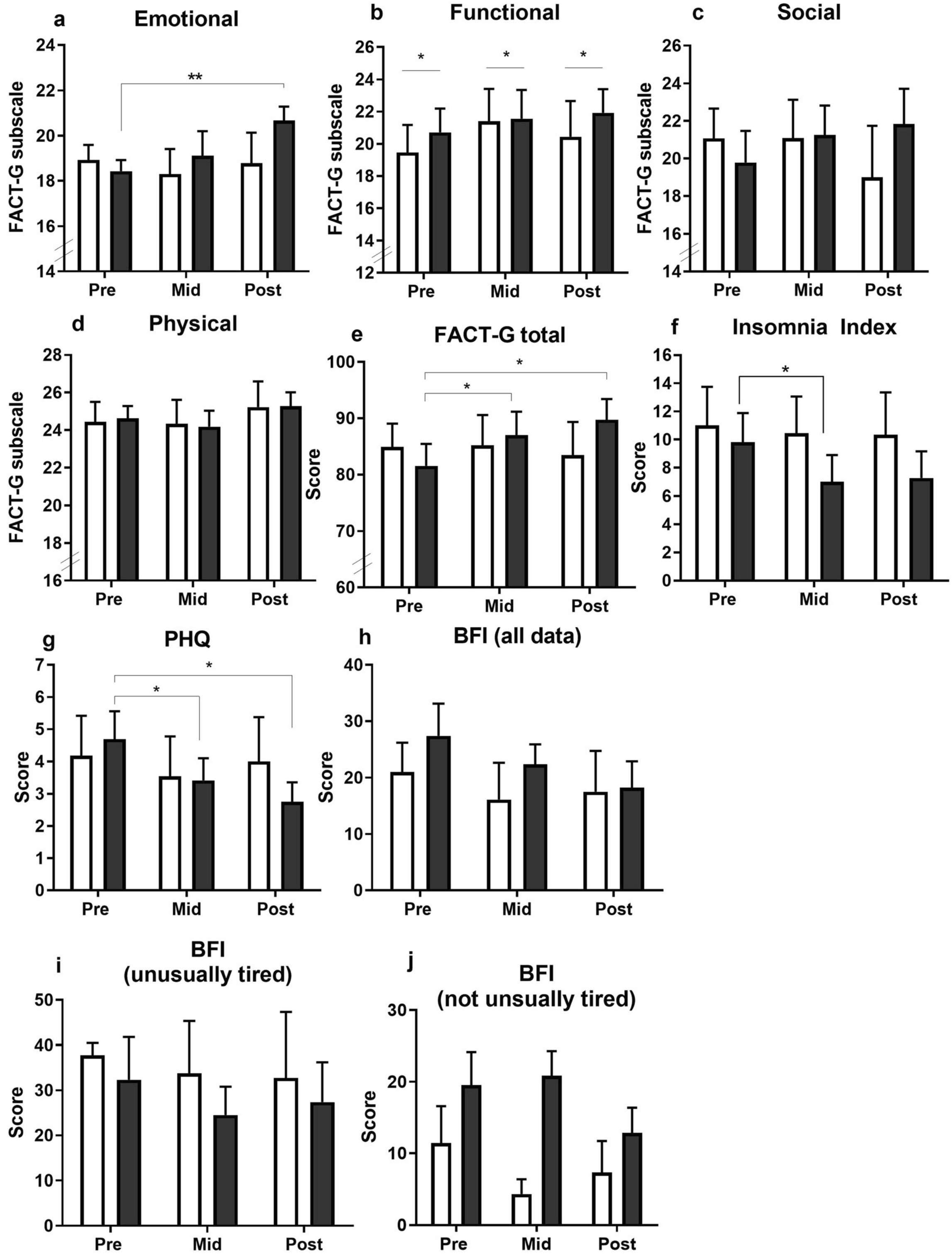

Fig. 1 Psychosocial measures. Open bars (singly trained patients), closed bars (paired patients), mean (SE). **a** Emotional well-being was significantly improved in paired patients. **b** Functional well-being had a significant main effect of time. **c**, **d** No differences in social or physical well-being. **e** Total FACT-G scores were significantly improved in paired patients at both time points. **f** Paired patients had significant improvements in insomnia symptoms; lower scores reflect improved symptoms. **g** Significant main effect of time for PHQ scores, paired group had significant improvements in depressive symptoms at both time points, reduced scores reflect improved symptoms. **h** No differences in BFI scores (acute fatigue within the past 24 h) when all data were analyzed together; reduced scores reflect improved symptoms. **i** No differences in acute fatigue in patients who were unusually tired (over the past week). **j** Significant main effect of group in patients who were not unusually tired (over the past week), *$p < 0.05$. Abbreviations: FACT-G, Functional Assessment of Cancer Therapy-General; PHQ-9, Patient Health Questionnarire-9; BFI, Brief Fatigue Inventory

Table 1 Psychosocial outcome measures, mean (SD). +Main effect of time (2-way ANOVA) $p < 0.05$; *$p < 0.05$, **$p < 0.01$, post hoc multiple comparisons tests, significantly different from pre-intervention in the paired group. Abbreviations: *FACT-G*, Functional Assessment of Cancer Therapy-General; *QOL*, quality of life; *PHQ-9*, Patient Health Questionnarire-9; *BFI*, Brief Fatigue Inventory

	Single			Pair		
	Pre	Mid	Post	Pre	Mid	Post
FACT-G (QOL)						
Emotional	18.9 (2.4)	18.3 (3.5)	18.8 (4.1)	18.4 (1.8)	19.1 (3.3)	20.7 (2.1)**
Functional	19.5 (6.2)	21.4 (6.4)	20.4 (6.7)+	20.7 (5.5)	21.6 (5.4)	21.9 (5.1)+
Social	20.8 (5.7)	21.1 (6.8)	19.0 (8.2)	19.8 (6.3)	21.3 (5.4)	21.8 (6.5)
Physical	24.4 (3.2)	24.3 (3.8)	25.2 (4.1)	24.6 (3.6)	24.2 (2.7)	25.3 (2.3)
Total	84.8 (14.7)	85.2 (17.0)	83.4 (17.7)	81.5 (14.8)	87.0 (12.6)*	89.8 (12.8)*
Insomnia						
Insomnia Index	11.0 (8.3)	10.4 (7.8)	10.3 (9.0)	9.8 (6.9)	7.0 (6.3)*	7.3 (6.3)
Depression						
PHQ-9	4.2 (3.9)	3.5 (4.1)	4.0 (4.1)	4.7 (3.1)	3.4 (2.4)*	2.8 (2.1)*
Fatigue						
BFI (all data)	23.4 (19.5)	16.1 (20.6)	17.5 (22.8)	25.4 (21.1)	22.3 (12.3)	18.3 (16.1)
BFI (usually tired)	37.8 (5.4)	33.8 (23.2)	32.8 (29.2)	32.3 (23.3)	24.5 (15.4)	27.4 (19.7)
BFI (not unusually tired)	11.5 (12.6)	4.3 (5.0)	7.3 (10.8)	19.6 (12.1)	20.8 (8.5)	12.9 (9.3)

significant improvements in emotional well-being from pre- to final time points ($p < 0.05$) and QOL from pre- to mid- and pre- to final time points ($p < 0.05$). However, the main effect of time was not significant for emotional well-being ($F(2, 28) = 3.253$, $p = 0.0537$) or total FACT-G scores ($F(2, 36) = 2.235$, $p = 0.1216$). Functional well-being had a significant main effect of time, but there were no differences between groups ($F(2, 35) = 3.871$, $p = 0.0303$). This indicates that functional well-being was improved regardless of training type whereas emotional well-being was improved only in the paired group. There was a tendency for a main effect of time for physical well-being, but this was not significant ($F(2, 39) = 2.868$, $p = 0.0689$); there were no differences between groups. There were no statistical differences in social well-being.

There was a significant main effect of time for PHQ ($F(2, 40) = 4.450$, $p = 0.0180$). Post hoc analyses revealed that the paired group had significant improvements in depressive symptoms from pre- to mid-, and pre- to final time points, and there were no significant differences in the singly trained group. Mean pre-intervention scores of both groups were less than 5, indicating that, on average, subjects had minimal depressive symptoms at baseline.

Paired patients had significant improvements in insomnia symptoms from pre- to mid-time points, while the individually trained patients did not exhibit significant changes. At baseline, both groups fell into the subthreshold insomnia classification. At the midpoint of the program, insomnia scores indicated that the paired group did not have clinically significant insomnia, while the singly trained group remained in the subthreshold insomnia category. The main effect of time was not significant ($F(2, 36) = 2.743$, $p = 0.0778$).

There were no differences in BFI scores when all data were analyzed with an ANOVA, regardless of the level of fatigue the participant experienced the week prior to the baseline assessment. When analyzing data from patients who reported unusual tiredness, there were no statistical differences in the main effects of time ($F(2, 15) = 0.6374$, $p = 0.5424$), or group ($F(1, 8) = 0.1720$, $p = 0.6893$). However, patients who were *not* feeling unusually tired at baseline had a significant main effect for group ($F(1, 12) = 6.318$, $p = 0.0272$), but not for time ($F(2, 21) = 1.175$). There were no significant differences between groups as detected with multiple comparisons tests. The number of patients who reported feeling chronically fatigued increased from pre- to mid-time points in both groups. At the final time point, the number of subjects who reported feeling unusually tired was reduced in both groups.

At baseline, both groups had similar body weights. The intervention had no significant effect on body weight or body fat. Cardiorespiratory fitness and muscular strength improved similarly between groups. With regard to cardiorespiratory fitness, there was a significant main effect of time ($F(1, 21) = 23.89$, $p < 0.0001$). Multiple comparisons analyses revealed that both paired and individual exercisers had significant improvements in VO_2peak ($p < 0.01$). Likewise, the 1-RMs of all muscle groups, except for the leg curl (hamstring strength), had a significant main effect of time, where both paired and individually trained patients showed significant improvements: chest press ($F(1, 21) = 40.73$, $p < 0.0001$); military shoulder press ($F(1, 20) = 20.93$, $p = 0.0002$); seated rhomboid row ($F(1, 21) = 43.59$, $p < 0.0001$); leg press ($F(1, 21) = 14.45$, $p < 0.0011$); leg extension ($F(1, 21) = 21.21$, $p < 0.0002$). The 1-RM of latissimus dorsi pulldown had significant main effects of time ($F(1, 21) = 18.15$, $p < 0.0003$) and group ($F(1, 21) = 6.051$ $p < 0.0227$). Hamstring strength had a main effect of time ($F(1, 21) = 22.24$, $p < 0.0001$), but post hoc tests showed that only the paired group had significantly improved strength.

Lower body muscular endurance significantly improved in paired but not in singly trained patients ($p < 0.001$); there was a significant main effect of time ($F(1, 21) = 22.13$, $p = 0.0001$). Hamstring flexibility increased from pre- to post-intervention, as demonstrated with a significant main effect of time ($F(1, 21) = 4.541$, $p = 0.0451$); there were no differences between groups. Figure 2 and Table 2 describe physical fitness results.

Discussion

Patients who exercised in pairs exhibited significant improvements in QOL, insomnia symptoms, and depression, while patients who exercised individually did not have the same benefit. Even more, these improvements were reported at the midpoint of the exercise program, even in patients with minimal to moderate psychosocial disturbance. At the final time point, patients reported maintenance of these improvements in depressive symptoms and QOL, but insomnia scores were not significantly different. The lack of statistical difference may be related to the large variation in responses.

Although there was a trend toward improved scores at the midpoint, paired patients did not report statistically improved emotional well-being until the final time point. Both individually trained and paired patients had improvements in functional well-being, indicating the type of training did not affect the functional aspect. Interestingly, this effect was not observed for physical or social well-being.

While there were no differences in fatigue as measured with the BFI, there was a downward trend in fatigue in the short term, particularly in the paired group (Fig. 1h). However, acute fatigue scores from patients who did not report unusual tiredness a week prior to the baseline assessment showed a significant effect of group, indicating that the type of training affected acute fatigue (Fig. 1j). In essence, individually trained patients tended to perceive decreased levels of acute fatigue while paired patients tended to report greater levels of acute fatigue (Fig. 1j). This suggests that non-chronically fatigued patients, who exercise in pairs may expect to feel more fatigued as a result of exercising with a partner. This may be a result of greater exertion during the training when stimulated by their partner. We observed that paired patients developed camaraderie and motivated each other to achieve longer cardiovascular exercise durations or engage in more challenging resistance training exercises (unpublished observations). This may have accounted for the increased perception of acute fatigue that the paired patients experienced.

Not only does external motivation increase exertion, but this may also be influenced by social connection. Psychosocial data from the current study suggest that the paired group experienced positive, social interactions to a greater degree than the individually trained group. It is known that neurotransmitters affect how adults perceive social emotional cues. Increased serotonin levels are associated with decreased stress sensitivity and a brighter outlook [26]. Social bonding and reward circuits are associated with dopaminergic stimulation [27]. This is pertinent as the exercise-related central governor theory and psychological-motivational model propose that changes in these neurotransmitters affect perceived exertion during exercise [28]. It is plausible that social interaction–mediated changes in serotonin and dopamine levels altered the neural impulses that controlled exercising muscles [28, 29], reducing the perception of exertion and improving exercise tolerance [30]. As a result, paired patients may have inadvertently exercised at a higher intensity than intended, especially during resistance training. In turn, this may have increased the perception of acute fatigue (short term) in the paired group. Furthermore, this provides an explanation for the significant improvements of hamstring strength and lower body muscular endurance in the paired but not the individually trained group.

Still, even with increased perceptions of acute fatigue, paired exercisers can also expect to have improved sleep patterns, fall asleep with greater ease, and have improved sleep quality. These findings show a dichotomy between insomnia and perceived fatigue, where patients may "deal with fatigue" for a temporary time period, but as a result have improved sleep quality. In addition to the benefit related to social interaction, the finding that the paired patients had improved insomnia symptoms may be related to the fact that they completed their cancer treatment. Enhanced outcomes are more likely to be observed in patients who have completed treatment compared to those still receiving treatment and in those achieving greater exercise dose [31].

Studies analyzing depression prior to COVID-19 showed that 27% of cancer patients report depression during cancer treatment, and 21% report continued depressive symptoms within 1 year, with 15% reporting continued depression ≥ 1 year from cancer diagnosis [32]. During the pandemic, 36 to 68% and 31 to 75% of cancer patients reported anxiety and depression, respectively [33, 34]. Furthermore, women have greater vulnerability to anxiety during the pandemic when compared to men [34]. Female cancer patients have worsened predicted outcomes of perceived cognitive function and depression when measured during the pandemic [35]. The effect

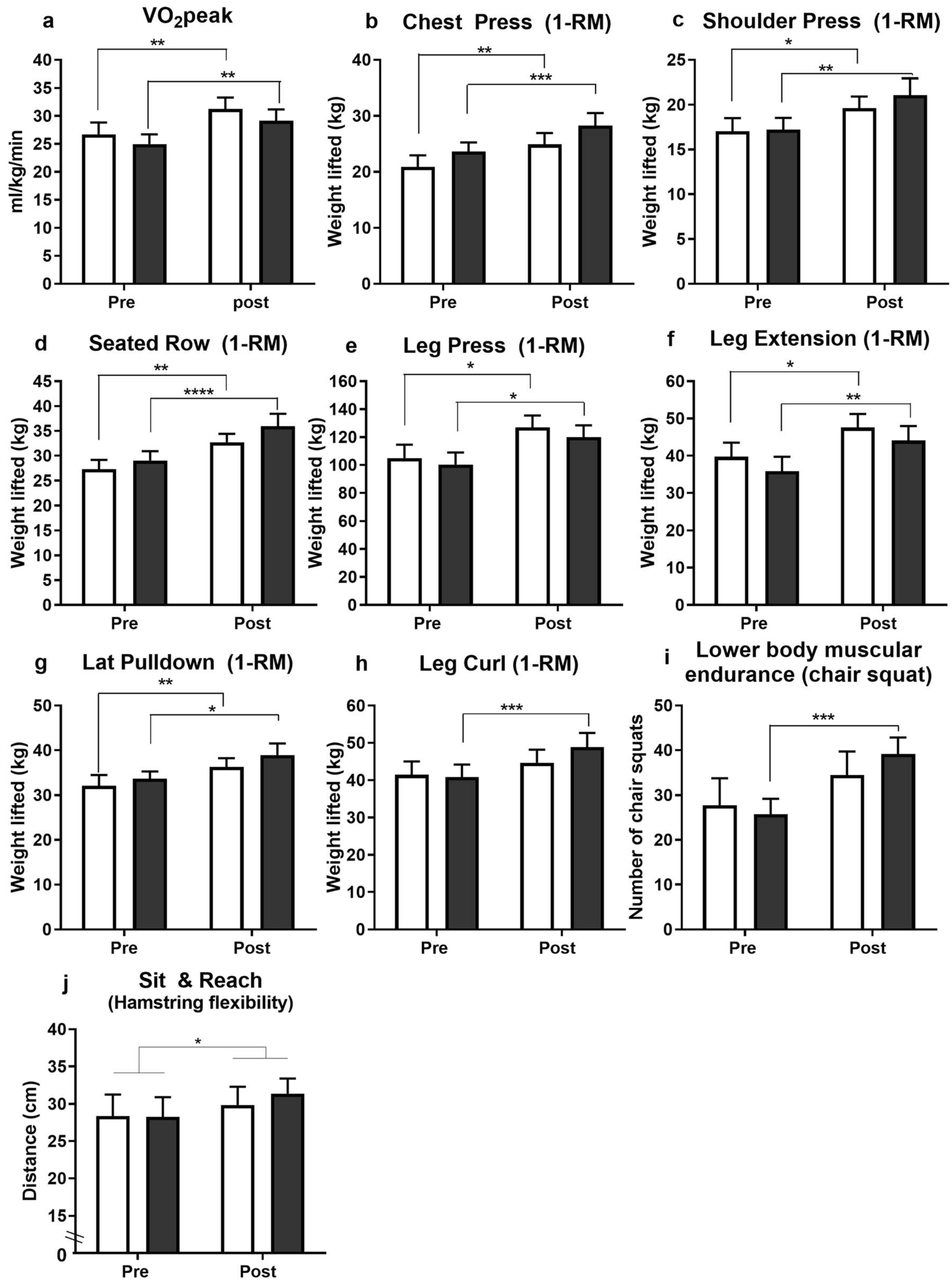

Fig. 2 Physical fitness measures. Open bars (singly trained patients), closed bars (paired patients), mean (SE). **a**–**f** Significant main effect of time; Bonferroni's post hoc test was used to show paired and singly trained patients had significant improvements from pre- to post-intervention. **g** Latissimus dorsi pulldown, significant main effects of time and group; post hoc test showed paired and singly trained patients had significant improvements from pre- to post-intervention. **h** and **i** Significant main effect of time, but only the paired group had significant improvements in lower body strength and endurance, respectively. **j** Significant main effect of time, no differences between groups. $^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$, $^{****}p < 0.0001$. Abbreviations: VO_2peak, peak oxygen consumption; 1-RM, one-repetition maximum

Table 2 Physical fitness measures, mean (SD). +Main effect of time (2-way ANOVA), $p < 0.05$; *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$, ****$p < 0.0001$, post hoc multiple comparisons tests significantly different from pre-intervention. Abbreviations: *VO_2peak*, peak oxygen consumption; *1-RM*, 1-repetition maximum; *SLS*, single leg stance; *EO*, eyes open; *EC*, eyes closed; *L*, left; *R*, right

	Single		Pair	
	Pre	Post	Pre	Post
Anthropometric measurements				
Body weight (kg)	73.1 (23.4)	75.1 (26.6)	73.1 (18.2)	72.3 (20.1)
% body fat (skinfolds)	34.6 (8.6)	33.1 (5.3)	32.8 (9.6)	33.4 (9.0)
Cardiorespiratory fitness				
VO_2peak (ml/kg/min)	26.6 (8.4)	31.3 (6.7)**	26.0 (6.3)	29.1 (7.1)**
1-RM (muscular strength, kg)				
Chest press	20.9 (6.9)	24.9 (6.8)**	23.6 (5.7)	28.3 (7.8)***
Shoulder press	17.0 (4.9)	19.6 (4.3)*	17.2 (4.3)	21.1 (6.2)**
Seated row	27.3 (6.3)	32.7 (5.7)**	29.0 (6.6)	35.9 (8.6)****
Leg press	105.0 (30.6)	127.0 (26.6)*	100.3 (30.1)	120.0 (29.5)*
Leg extension (quadriceps)	39.7 (12.7)	47.6 (12.1)*	35.8 (13.6)	44.1 (13.6)**
Latissimus dorsi pulldown	32.1 (6.8)	36.3 (6.6)**	33.6 (6.1)	38.9 (8.9)*
Leg curl (hamstrings)	41.1 (11.9)	44.7 (11.5)	40.9 (11.6)	48.9 (13.1)***
Muscular endurance				
Chair squat test (reps)	28 (21)	35 (19)	25 (10)	39 (12)***
Flexibility				
Sit and reach (cm)	26.8 (9.6)	29.9 (8.1)	30.2 (10.7)	31.4 (7.1) +
Balance				
SLS EOR (time, seconds)	34.7 (15.9)	40.9 (9.1)	36.6 (12.5)	42.7 (7.8) +
SLS EOL (time, seconds)	32.1 (16.4)	40.9 (11.0)	35.5 (14.6)	35.3 (15.0)
SLS ECR (time, seconds)	9.6 (13.0)	12.0 (13.3)	12.6 (12.6)	14.4 (12.4)
SLS ECL (time, seconds)	8.9 (7.8)	13.5 (13.9)	11.9 (14.6)	15.8 (17.6) +

of cancer, compounded with the effect of the pandemic intensifies the need for programs targeting psychosocial health in cancer patients.

Paired exercise has a larger, positive effect on QOL compared to individual exercise and these effects were demonstrated when applying scientific-based exercise guidelines for cancer patients. The benefit of exercise is amplified by exercising in pairs as it reverses social isolation and fosters cohesion. Also, paired exercise had similar effects on cardiovascular fitness as compared to exercising individually, which is consistent with previous research [36]. While paired exercise resulted in similar improvements in overall fitness compared to single exercisers, paired exercise improved a greater number of fitness parameters. Together, the data indicates that paired exercise is superior to individual exercise with regard to both psychosocial and physical health.

Limitations

Although exercise prescriptions of paired and individually trained groups were matched for RPE, the positive social interactions, and positive emotions in the paired group may have reduced the perception of effort compared to if they had exercised alone. It is plausible that the paired group exercised at higher intensities than the singly trained group. Our sample size is another limitation of the study. A larger sample size may reveal additional effects of the intervention. COVID-19 impacted our ability to continue with data collection, yet with the recognition that exercise for cancer survivors would be even more central under the current and near-future pandemic conditions, communicating the findings seemed of increased relevance.

Conclusions

Paired cancer patients but not singly trained patients had improvements in QOL, emotional well-being, and insomnia and depressive symptoms. Individual training resulted in the similar cardiorespiratory fitness improvements, but these patients exhibited smaller gains in lower body muscular function when compared to the paired group. Paired exercise training sessions foster cohesion between partners, resulting in greater improvements in psychosocial well-being and physical fitness when compared to singly trained exercisers.

Acknowledgements We would like to acknowledge Sash-sha Collier for her work on this project.

Availability of data and material Not applicable
Code availability Not applicable

Author contribution Paulette M. Yamada participated in research design, writing of the paper, performance of the research, and data analysis, and received funding from the Hubert Everly Foundation, an internal mechanism of the College of Education at the University of Hawaii.

Cheri Teranishi-Hashimoto participated in research design and performance of the research.

Erin O. Bantum participated in research design, writing of the paper, and data analysis.

Funding Partial financial support was received from the Hubert Everly Foundation, an internal mechanism of the College of Education at the University of Hawaii, Author: 1. The authors report no involvement in the research by the sponsor that could have influenced the outcome of the work.

Declarations

Ethics approval Research activities were approved by the Institutional Review Board in accordance with the Helsinki Declaration (#2018-00167).

Consent to participate Prior to participation, written and verbal informed consents were obtained from all individual participants in the study.

Consent for publication Patients signed informed consents acknowledging that their data would be used for research publication.

Conflict of interest The authors declare no competing interests.

References

1. Chida Y, Hamer M, Wardle J, Steptoe A (2008) Do stress-related psychosocial factors contribute to cancer incidence and survival? Nat Clin Pract Oncol 5(8):466–475. https://doi.org/10.1038/ncponc1134
2. Roud PC (1987) Psychosocial variables associated with the exceptional survival of patients with advanced malignant disease. J Natl Med Assoc 79(1):97–102
3. Groenvold M, Petersen MA, Idler E, Bjorner JB, Fayers PM, Mouridsen HT (2007) Psychological distress and fatigue predicted recurrence and survival in primary breast cancer patients. Breast Cancer Res Treat 105(2):209–219. https://doi.org/10.1007/s10549-006-9447-x
4. Pachman DR, Price KA, Carey EC (2014) Nonpharmacologic approach to fatigue in patients with cancer. Cancer J 20(5):313–318. https://doi.org/10.1097/PPO.0000000000000064
5. Linden W, Vodermaier A, Mackenzie R, Greig D (2012) Anxiety and depression after cancer diagnosis: prevalence rates by cancer type, gender, and age. J Affect Disord 141(2-3):343–351. https://doi.org/10.1016/j.jad.2012.03.025
6. Puetz TW, Herring MP (2012) Differential effects of exercise on cancer-related fatigue during and following treatment: a meta-analysis. Am J Prev Med 43(2):e1–e24. https://doi.org/10.1016/j.amepre.2012.04.027
7. Brown JC, Huedo-Medina TB, Pescatello LS, Ryan SM, Pescatello SM, Moker E, LaCroix JM, Ferrer RA, Johnson BT (2012) The efficacy of exercise in reducing depressive symptoms among cancer survivors: a meta-analysis. PLoS One 7(1):e30955. https://doi.org/10.1371/journal.pone.0030955
8. Sweegers MG, Altenburg TM, Chinapaw MJ, Kalter J, Verdonck-de Leeuw IM, Courneya KS, Newton RU, Aaronson NK, Jacobsen PB, Brug J, Buffart LM (2018) Which exercise prescriptions improve quality of life and physical function in patients with cancer during and following treatment? A systematic review and meta-analysis of randomised controlled trials. Br J Sports Med 52(8):505–513. https://doi.org/10.1136/bjsports-2017-097891
9. Cramp F, Byron-Daniel J (2012) Exercise for the management of cancer-related fatigue in adults. Cochrane Database Syst Rev 11:CD006145. https://doi.org/10.1002/14651858.CD006145.pub3
10. Colloca G, Colloca P (2016) The effects of social support on health-related quality of life of patients with metastatic prostate cancer. J Cancer Educ 31(2):244–252. https://doi.org/10.1007/s13187-015-0884-2
11. Shand LK, Cowlishaw S, Brooker JE, Burney S, Ricciardelli LA (2015) Correlates of post-traumatic stress symptoms and growth in cancer patients: a systematic review and meta-analysis. Psychooncology 24(6):624–634. https://doi.org/10.1002/pon.3719
12. Ibrahim EM, Al-Homaidh A (2011) Physical activity and survival after breast cancer diagnosis: meta-analysis of published studies. Med Oncol 28(3):753–765. https://doi.org/10.1007/s12032-010-9536-x
13. Kroenke CH, Michael YL, Poole EM, Kwan ML, Nechuta S, Leas E, Caan BJ, Pierce J, Shu XO, Zheng Y, Chen WY (2017) Postdiagnosis social networks and breast cancer mortality in the After Breast Cancer Pooling Project. Cancer 123(7):1228–1237. https://doi.org/10.1002/cncr.30440
14. Leach HJ, Potter KB, Hidde MC (2019) A group dynamics-based exercise intervention to improve physical activity maintenance in breast cancer survivors. J Phys Act Health 16(9):785–791. https://doi.org/10.1123/jpah.2018-0667
15. Leach HJ, Covington KR, Voss C, LeBreton KA, Harden SM, Schuster SR (2019) Effect of group dynamics-based exercise versus personal training in breast cancer survivors. Oncol Nurs Forum 46(2):185–197. https://doi.org/10.1188/19.ONF.185-197
16. American College of Sports Medicine Guidelines for Exercise Testing and Prescription (2018) Riebe D, Erhman J, Liguori G, Magal M (Eds) 10th ed. Wolters Kluwer, Baltimore.
17. Schmitz KH, Courneya KS, Matthews C, Demark-Wahnefried W, Galvao DA, Pinto BM, Irwin ML, Wolin KY, Segal RJ, Lucia A, Schneider CM, von Gruenigen VE, Schwartz AL, American College of Sports M (2010) American College of Sports Medicine roundtable on exercise guidelines for cancer survivors. Med Sci Sports Exerc 42(7):1409–1426. https://doi.org/10.1249/MSS.0b013e3181e0c112
18. Brown JM, Shackelford D, Hipps M, Hayward R (2019) Evaluation of an exercise-based phase program as part of a standard care model for cancer survivors. Translationl Journal of ACSM 4(7):45–54
19. Brady MJ, Cella DF, Mo F, Bonomi AE, Tulsky DS, Lloyd SR, Deasy S, Cobleigh M, Shiomoto G (1997) Reliability and validity of the Functional Assessment of Cancer Therapy-Breast quality-of-life instrument. J Clin Oncol 15(3):974–986. https://doi.org/10.1200/JCO.1997.15.3.974
20. Badia Llach X, Herdman M, Schiaffino A (1999) Determining correspondence between scores on the EQ-5D “thermometer” and a 5-point categorical rating scale. Med Care 37(7):671–677. https://doi.org/10.1097/00005650-199907000-00007
21. Mendoza TR, Wang XS, Cleeland CS, Morrissey M, Johnson BA, Wendt JK, Huber SL (1999) The rapid assessment of fatigue severity in cancer patients: use of the Brief Fatigue Inventory. Cancer 85(5):1186–1196. https://doi.org/10.1002/(sici)1097-0142(19990301)85:5<1186::aid-cncr24>3.0.co;2-n

22. Gagnon C, Belanger L, Ivers H, Morin CM (2013) Validation of the Insomnia Severity Index in primary care. J Am Board Fam Med 26(6):701–710. https://doi.org/10.3122/jabfm.2013.06.130064
23. Spitzer RL, Kroenke K, Williams JB (1999) Validation and utility of a self-report version of PRIME-MD: the PHQ primary care study. Primary Care Evaluation of Mental Disorders. Patient Health Questionnaire. JAMA 282(18):1737–1744. https://doi.org/10.1001/jama.282.18.1737
24. Hayward R, personal communication (July 24, 2017) Clinical cancer exercise specialist workshop. University of Northern Colorado Cancer Rehabilitation Institute, Greeley, CO
25. Mayhew JL, Prinster JL, Ware JS, Zimmer DL, Arabas JR, Bemben MG (1995) Muscular endurance repetitions to predict bench press strength in men of different training levels. J Sports Med Phys Fitness 35(2):108–113
26. Kiser D, Steemers B, Branchi I, Homberg JR (2012) The reciprocal interaction between serotonin and social behaviour. Neurosci Biobehav Rev 36(2):786–798. https://doi.org/10.1016/j.neubiorev.2011.12.009
27. Vrticka P, Vuilleumier P (2012) Neuroscience of human social interactions and adult attachment style. Front Hum Neurosci 6:212. https://doi.org/10.3389/fnhum.2012.00212
28. Noakes TD (2000) Physiological models to understand exercise fatigue and the adaptations that predict or enhance athletic performance. Scand J Med Sci Sports 10(3):123–145. https://doi.org/10.1034/j.1600-0838.2000.010003123.x
29. Davis JM, Bailey SP (1997) Possible mechanisms of central nervous system fatigue during exercise. Med Sci Sports Exerc 29(1):45–57. https://doi.org/10.1097/00005768-199701000-00008
30. Marcora SM (2008) Do we really need a central governor to explain brain regulation of exercise performance? Eur J Appl Physiol 104(5):929–931; author reply 933-925. https://doi.org/10.1007/s00421-008-0818-3
31. Mercier J, Savard J, Bernard P (2017) Exercise interventions to improve sleep in cancer patients: a systematic review and meta-analysis. Sleep Med Rev 36:43–56. https://doi.org/10.1016/j.smrv.2016.11.001
32. Krebber AM, Buffart LM, Kleijn G, Riepma IC, de Bree R, Leemans CR, Becker A, Brug J, van Straten A, Cuijpers P, Verdonck-de Leeuw IM (2014) Prevalence of depression in cancer patients: a meta-analysis of diagnostic interviews and self-report instruments. Psychooncology 23(2):121–130. https://doi.org/10.1002/pon.3409
33. Chen G, Wu Q, Jiang H, Zhang H, Peng J, Hu J, Chen M, Zhong Y, Xie C (2020) Fear of disease progression and psychological stress in cancer patients under the outbreak of COVID-19. Psychooncology. 29:1395–1398. https://doi.org/10.1002/pon.5451
34. Romito F, Dellino M, Loseto G, Opinto G, Silvestris E, Cormio C, Guarini A, Minoia C (2020) Psychological distress in outpatients with lymphoma during the COVID-19 pandemic. Front Oncol 10:1270. https://doi.org/10.3389/fonc.2020.01270
35. Swainston J, Chapman B, Grunfeld EA, Derakshan N (2020) COVID-19 Lockdown and its adverse impact on psychological health in breast cancer. Front Psychol 11:2033. https://doi.org/10.3389/fpsyg.2020.02033
36. Dieli-Conwright CM, Courneya KS, Demark-Wahnefried W, Sami N, Lee K, Sweeney FC, Stewart C, Buchanan TA, Spicer D, Tripathy D, Bernstein L, Mortimer JE (2018) Aerobic and resistance exercise improves physical fitness, bone health, and quality of life in overweight and obese breast cancer survivors: a randomized controlled trial. Breast Cancer Res 20(1):124. https://doi.org/10.1186/s13058-018-1051-6