Twelve-Weeks of Virtual and In-Person Exercise Training Improve Static and Dynamic Balance in Female Cancer Patients

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Abstract

Background: Balance is important for maintaining activities of daily living and functional independence. Whether balance is improved in cancer patients after fitness training is unclear. The purpose of this study was to determine if 12-weeks of exercise improves balance and posture in female cancer patients.

Methods: Thirty-eight female cancer patients were enrolled. Of the 16 patients who completed the program (mean age±SD: 65±10 years), 12 participants were novice and 4 were experienced exercisers. Six-weeks of exercise sessions were provided in-person and the remaining sessions were virtually delivered. The American College of Sports Medicine's exercise recommendations were followed. Novice exercises received 36, 90-minute exercise sessions (3x/week) and experienced exercisers had 24, 90-minute sessions (2x/week). Posture was measured using the plumb line method and overhead squat test; balance was measured using the unipedal single leg stance and limits of stability (LOS). Body composition, cardiorespiratory fitness, muscular strength, and flexibility were also measured. Two-way repeated measures ANOVAs and Bonferroni's multiple comparison tests were used to determine significant differences.

Results: Balance on the left leg (eyes closed) and LOS with leftward excursion were significantly improved in experienced exercisers ($P=0.0029$), but not in the novice group ($P=0.0013$). Qualitative data showed that experienced exercisers had improved static and dynamic postural alignment of the lower body.

Conclusions: While cardiorespiratory and muscular fitness significantly improved in the novice group, these patients did not show balance and postural improvements. Only the experienced exercisers had significant improvements in static and dynamic balance and lower body posture.

Introduction

Balance, posture and muscular performance are important for maintaining functional independence and activities of daily living (ADL) [1–3]. Posture is the orientation of a body segment relative to a gravitational vector, and it is affected by the downward pull of gravity [4]. Balance is related to the inertial forces acting on the body, and inertial characteristics of individual body segments [4], and more simply, the ability to prevent falls [5]. Physical fitness not only affects the ability to accomplish ADL, but it relates to psychosocial functioning as impaired balance could lead to social isolation, activity avoidance and fear of falls [6]. As such, the ability to accomplish ADL is positively associated with QOL [7].

Cancer treatments can affect patients' quality of life (QOL) and hinder their ability to engage in physical activity [8]. Balance may be aggravated by a lack of muscle conditioning and flexibility, poor posture maintenance and neurotoxic chemotherapeutic agents of therapy [9, 10]. In the case of breast cancer, treatments such as surgery can result in dysfunction and pain in the upper limbs, ultimately limiting range of motion (ROM) in flexion, abduction, and external rotation shoulder movements [11]. Surgery or radiation can cause fibrosis or densification of fascial structures that decrease limb mobility [11]. A decrease in ROM and pain can result in failure to be active, further provoking poor muscular function, which can negatively impact posture [11]. Proper sagittal spinal alignment and muscle strength improves balance, and reduces the risk of falls [2]. Since the body can be interpreted as a kinetic chain, changes in the upper body and spine alignment contribute to deviations in the lower body, which could impair balance [12].

A balance-based exercise intervention has shown to partially improve postural instability in cancer patients with severe chemotherapy-induced peripheral neuropathy (CIPN) [13]. However, the impact of general fitness programs on balance is unclear. Exercise programs which follow the American College of Sports Medicine's (ACSM) recommendations for cancer patients, which target cardiovascular and muscular fitness, and flexibility improve aerobic and muscular fitness [14] but its impact on balance and posture are not clear. The impact of exercise on posture and balance in cancer patients has not been comprehensively studied and knowledge is often derived from diabetic neuropathy studies [13]. Thus, the purpose of this study was to evaluate the effect of 12-weeks of exercise training on posture and balance in novice and experienced female exercisers who were diagnosed with cancer.

Methods

Design and Procedures

Thirty-eight female patients who completed cancer treatment were enrolled. Patients were recruited through a state-wide referral network comprised of oncologists, radiologists, and surgeons. All participants received exercise clearance from their oncology-related 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 provider, literacy in English, and ability to attend exercise sessions for 12 weeks. Prior to participation, patients provided their verbal and written consent. Research activities were approved by the Institutional Review Board (IRB, #2018 − 00167).

Initial and final fitness testing took place in-person; final assessments were conducted during the pandemic using additional safety precautions as approved by the IRB. At the mid-point of the exercise intervention, the COVID-19 pandemic emerged, precluding in-person, individualized exercise training. All participants were given the option to continue their program virtually during the quarantine. Of the 38 patients, 16 completed the intervention (mean age±SD: 65±10 years). Twelve of these patients were new to the program and these novice exercisers received 3 exercise sessions per week (36 sessions total). Four patients were experienced exercisers, having completed a 12-week face-to-face exercise program prior to their current enrollment. In the current study, they received 2 exercise sessions per week (24 sessions total). Participants included those diagnosed with breast cancer (invasive ductal carcinoma and invasive lobular carcinoma in either the right or left breast, n = 14), endometrial carcinoma (n = 1) and Non-Hodgkin's lymphoma (n = 1). Cancer treatments completed by breast cancer patients included breast lumpectomy or mastectomy (right, left or both sides, n = 13), conserving therapy (n = 1), reconstruction (n

= 3), radiation (n = 7), chemotherapy (n = 6), and hormonal therapy (utilizing Herceptin, Anastrozole and/or Tamoxifen, n = 11).

Balance measures

Unipedal single leg stance (SLS) was used to measure static balance. Patients were instructed to balance on each bare foot, beginning with their dominant foot for as long as possible up to a maximum time of 45 seconds. This was performed with and without visual feedback, eyes open (EO) and eyes closed (EC), on both right (R) and left (L) feet. The best score out of 3 trials was recorded for EOR, EOL, ECR and ECL.

Dynamic balance was measured with the Bertec Balance Screener (Columbus, OH). Limits of Stability (LOS) were evaluated in the anterior-posterior and medio-lateral directions on a flat/firm surface with visual feedback. Patients were directed to sway in each direction including forward (F), back (B), right (R) and left (L) in order to approach the limits of their base of support while maintaining foot placement and complete foot contact with the force plate. The LOS values were normalized to their age- and height-predicted values and expressed as a percentage. The LOSF, LOSB, LOSR, LOSL and overall LOS percentile scores were recorded.

Postural measures

All postural measurements were qualitatively assessed. Subjective descriptions such as “mild” or “significant” variations in posture have used to describe the severity of an abnormality [15]. However, the use of this method is limited by subjective observations and therefore, the presence or absence of a deviation was recorded and frequencies of postural deviations were analyzed in each group.

Overhead Squat. The National Academy of Sports Medicine’s (NASM) overhead squat assessment was used to assess muscle imbalance and postural deviations during a dynamic squat [16]. Patients were asked to stand with their feet-distance apart, toes pointing forward, heels on the floor and arms extended overhead. Then, they were asked to slowly squat down to sit in a chair while evaluators noted upper and lower body anatomical deviations (i.e., forward head/arms/torso, knees and toes pointing inward/outward).

Plumb line Method. This method was used to assess posture deviations in a static position in anterior, sagittal and posterior views. Patients were asked to stand comfortably in the anatomical position with their feet shoulder width apart and arms hanging to the side while evaluators noted prominent deviations. In the sagittal view, the presence or absence of forward head, forward lean, scapular protraction/retraction, kyphosis, lordosis and posterior or anterior pelvic tilt was recorded. In the anterior view, the following deviations were notated: head tilt or rotation, shoulder elevation, high hip, valgus or varus knee, pronation or supination of feet and inward or outward pointing toes. The posterior view was used to detect weight shifts, hyperextension of the knees or elevation of hips.

Cardiorespiratory, body composition, flexibility, muscular 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 composition, muscular strength, flexibility and cardiovascular endurance were measured pre- and post-intervention. These measures helped to identify baseline fitness characteristics as well as show changes in fitness. Body composition was measured with bioimpedance analysis (Omron, HMF306), waist circumference measurements, waist-to-hip ratios and body mass index. Lower body muscular strength was assessed using 1-repetition maximum (1-RM) tests using the horizontal leg press, seated leg extension and seated leg curl exercises. In cases where the 1-RM could not be achieved, a prediction equation was used to estimate 1-RM using the maximum weight lifted for 10 or less repetitions [17]. Hamstring flexibility was measured with the modified sit-and-reach test. Upper body flexibility was measured with the back scratch test with the right or left arm overhead with fingers of opposite hands reaching toward each other. A negative score indicates the fingers did not overlap while a positive score indicates overlapping of fingers. Cardiovascular endurance was measured with a treadmill protocol specific to the cancer population [18] where final speed and grade were used to estimate and maximal oxygen uptake (VO_2peak) [19]. The test was terminated upon volitional fatigue, the patient's request to stop or if contraindications to exercise were observed.

Exercise Training

Fifty percent of the exercise intervention was provided in person with the remaining 50% being provided virtually due to COVID-19 restrictions. The in-person training was led by an exercise specialist knowledgeable in cancer exercise rehabilitation principles. Exercise specialists were trained using a specialized curriculum [20]. Patients were led through 90-minute exercise sessions and at least 1 rest day was placed between training sessions. Specifically, patients completed 30 minutes of cardiovascular training and 5–7 resistance training exercises at a workload of 40–85% of the subject's 1-repetition maximum (1-RM). Heart rate reserve (40–85% of HRR) [21] and Borg's Rate of Perceived Exertion (RPE) were used to determine indices of physiological strains during cardiovascular training [22]. Heart rate (HR) was monitored throughout the session using a chest-based device that wirelessly connected to an external tablet (Polar H10, USA). Target RPE was 3–6 (on a scale of 0.5 to 10, where 0.5 corresponds to resting and 10 corresponds to maximal exertion). RPE was a necessary tool for patients who use pharmacological drugs that lower HR such as β-blockers, non-dihydropyridine calcium channel blockers and ivabradine [23]. RPE was reported after each exercise bout and helped to identify true physiological strain independent of HR response to exercise.

Balance was trained using foam pads, BOSU balls, stairs or other techniques to work on strengthening leg, foot and back muscles. Exercises that used tandem or split stances in resistance training exercises were used to train balance. With regard to postural training, exercise specialists used results of the NASM overhead squat assessment to identify specific muscles to stretch or strengthen with the goal of improving posture [24]. All exercise programs incorporated exercise training principles and followed recommendations of the ACSM for patients diagnosed with cancer, i.e., aerobic, resistance training, balance and flexibility training [19, 25]. Logbooks were used to document exercises and assure fidelity to the protocol.

Virtual programs followed the same guidelines listed above. Trainers provided the exercise program through email or Google Docs and patients reported their progress in the same manner or through phone or text messaging. Trainers utilized exercise equipment the patient had at home or outdoor activities (i.e., open water swimming, walking in the neighborhood) to create the exercise program. Trainers utilized online resources (i.e., videos which demonstrated the exercise) or shared videos of themselves performing the exercise. Trainers then relayed patient progress to administrators, and this correspondence was used to assure fidelity to the protocol.

Statistical analyses

Quantitative fitness data were analyzed with 2-way repeated measures ANOVAs with factors Time (pre, post) x Group (novice, experienced). Bonferroni's *posthoc* multiple comparisons tests were used to detect differences between groups pre- to post-intervention; significance was set at $P < .05$ (GraphPad Prism, version 8.0.0 for Windows, San Diego, CA). Pilot data were used in power analyses to show that with 9 subjects, there would be a 95% chance of detecting improved static balance with a mean improvement of 5 seconds and incorporating 10 subjects would result in a 95% chance of detecting improved dynamic balance (power, $1\text{-}\beta = 0.8$, one-tailed, SPSS ver. 27). Qualitative data for dynamic and static posture were organized into tables to show the frequencies of which a postural deviation was observed.

Results

The exercise intervention was effective in improving overall fitness. Pre-and post-fitness data are provided in Table 1. There was a main effect of time for VO_2peak ($F(1,13) = 7.491$, $P = 0.017$) and waist circumference ((F1,14) = 4.886, $P = 0.0442$). The novice group had significant improvements in cardiorespiratory fitness after the intervention ($P = 0.0154$). There was a main effect of time for the 1-RM leg extension ((F1,13) = 10.22, $P = 0.0070$) and 1-RM leg curl ((F1,13) = 6.209, $P = 0.0270$). Multiple comparison tests revealed the novice group had significantly improved quadriceps strength ($P = 0.0065$) but not hamstring strength after the intervention ($P = 0.0646$). No significant change in the 1-RM for the leg press was detected. For hamstring flexibility (sit and reach test), there was a main effect of time ($F(1,14) = 5.756$, $P = 0.0309$) and group ($F(1,14) = 14.86$, $P = 0.0018$); multiple comparisons tests showed a significant improvement in flexibility in the novice group but not in the experienced group. With regard to back scratch test with right shoulder external rotation and left shoulder internal rotation, there was a main effect of time ($F(1,14) = 28.50$, $P = 0.0001$); multiple comparison tests revealed significant improvements in both groups.

Table 1

Changes in fitness parameters after a 12-week exercise intervention in female cancer patients (Mean ± SD). VO_2peak (peak oxygen consumption); (1-RM) 1-repetition maximum, SLS (single leg stance), EO (eyes open), EC (eyes closed), L (left), R (right), LOS (limits of stability), F (forward), B (back).

	Novice (n = 12)		**Experienced (n = 4)**	
	Age: 65 ± 11 years		**Age: 64 ± 9 years**	
	Pre	**Post**	**Pre**	**Post**
Anthropometric Measurements				
Body weight (kg)	59.8 ± 9.9	59.7 ± 10.3	57.2 ± 14.6	56.5 ± 14.9
Body Mass Index	23.1 ± 4.0	23.3 ± 4.2	22.1 ± 4.7	21.8 ± 4.8
% Body Fat	36.3 ± 7.3	32.3 ± 10.4	32.1 ± 8.4	32.2 ± 8.9
Waist Circumference (cm)	76.2 ± 8.1	75.8 ± 9.0$^{\delta}$	76.5±14.6	73.3±11.6$^{\delta}$
Waist-to-Hip Ratio	0.82 ± 1.7	0.79 ± 0.06	0.89 ± 0.19	0.83 ± 0.06
Cardiorespiratory Fitness				
VO_2peak (ml/kg/min)	28.3 ± 10.5	34.3 ± 6.5$^{\delta}$*	31.9 ± 7.1	35.9 ± 1.1$^{\delta}$
Static Balance				
SLS EOR (time, sec)	39.7 ± 12.7	40.3 ± 11.5	45.0 ± 0.0	45.0 ± 0.0
SLS EOL (time, sec)	36.6 ± 14.0	38.9 ± 13.0	45.0 ± 0.0	45.0 ± 0.0
SLS ECR (time, sec)	17.2 ± 18.1	19.1 ±15.4	18.5 ± 9.7	31.1 ± 17.2
SLS ECL (time, sec)	15.4 ± 17.0	13.8 ± 12.8^{+}	14.3 ± 8.7	29.8 ± 12.2^{+}*
Dynamic Balance				
LOSF (%)	79.7 ± 26.2	91.7 ± 19.4	91.4 ± 22.8	99.4 ± 28.2
LOSB (%)	63.1 ± 26.9	67.6 ± 23.7	50.9 ± 14.7	54.8 ± 15.5
LOSR (%)	113.2 ± 10.2	123.7 ± 24.0	113.3 ± 17.9	119.6 ± 15.8
LOSL (%)	114.5 ± 131.4	123.4 ± 15.3^{+}	88.4 ± 15.6	122.3 ± 22.0^{+}*
Overall LOS (%)	84.6 ± 13.0	88.3 ± 5.7	87.1 ± 7.6	85.2 ± 2.9
1-RM (muscular strength, kg)				
Leg Press	82.1 ±9.1	91.6 ± 15.0$^{\delta}$	81.6 ± 33.4	85.3 ± 23.9$^{\delta}$

$^{\delta}$Significant main effect of time, $^{\beta}$ Significant main effects of time and group, $^{+}$ Significant main effect of time and significant interaction (2-way ANOVA), $P < 0.05$; *$p < 0.05$ Bonferroni's post-hoc comparisons test.

	Novice (n = 12) Age: 65 ± 11 years		Experienced (n = 4) Age: 64 ± 9 years	
Leg Extension	27.9 ± 6.8	38.4 ± 9.7$^{\delta}$*	29.8 ± 11.9	37.4 ± 8.5$^{\delta}$
Leg Curl	32.3 ± 3.2	37.5 ± 5.2	31.1 ± 7.9	36.5 ± 7.0
Flexibility				
Sit and reach (cm)	30.1 ± 4.8	34.1 ± 5.2$^{\beta}$*	20.4 ± 3.9	23.7 ± 7.2$^{\beta}$
Back scratch (R, cm)	-2.7 ± 7.3	-1.1 ±6.6$^{\delta}$*	-3.6 ± 6.3	− 0.2± 6.7$^{\delta}$*
Back scratch (L, cm)	-9.9 ± 8.0	-8.3 ± 7.9	-1.9 ± 2.2	-1.3 ± 6.7

$^{\delta}$Significant main effect of time, $^{\beta}$ Significant main effects of time and group, $^{+}$ Significant main effect of time and significant interaction (2-way ANOVA), P < 0.05; *p < 0.05 Bonferroni's post-hoc comparisons test.

Concomitant with improvements in fitness, static balance with the SLS test on the left foot without visual feedback was significantly improved. There was a significant main effect of time (F(1,14) = 9.349, P = 0.0085) and interaction (F(1,14) = 14.26, P = 0.002). Bonferroni's *posthoc* test revealed significant improvement in left-footed balance (EC) balance in the experienced group (P = 0.0029), but not in the new exercisers (P = 0.9679). No significant changes were detected in the other SLS conditions. Figure 1 illustrates the significant changes in fitness.

Likewise, there was a main effect of time for dynamic balance with leftward excursion (LOSL) (F(1,14) = 22.76, P = 0.0003) and interaction between time x group was significant (F(1,14 = 0.0148, P = 0.0148). The returning group had significant improvements in LOSL (p = 0.0013), while no changes were detected in the new group (P = 0.1325). All subjects reported right foot dominance with the exception of 2 patients in the novice group, and as such improvements in balance occurred on the non-dominant side.

Results of the static plumb line and dynamic NASM overhead squat assessments are shown in Tables 2 and 3, respectively. The frequency of each deviation was summed. In the novice group, knee and foot positioning (outward motion) and weight shifting worsened as measured with the dynamic postural assessment. A decline in foot positioning was also detected with the static postural assessment. With static posture, lordosis, elevation of the right shoulder, hyperextension of the knee was exaggerated after the intervention. Notably, there was improved knee and head positioning, reduced weight shifting and improved elevation of the left shoulder with static posture. Additionally, the novice group had a reduced incidence of foot flattening during the NASM squat test.

Table 2
Frequency of postural deviations during static plumb line assessment

	Novice (n = 12)		Experienced (n = 4)	
	Pre	**Post**	**Pre**	**Post**
Anterior View				
Shoulder elevation (R)	4	6 worsened	0	1 worsened
Shoulder elevation (L)	4	1 improved	2	0 improved
Valgus or Varus knee (R)	4	2 improved	1	0 improved
Valgus or Varus knee (L)	3	2 improved	1	0 improved
Head tilt (R)	1	0 improved	0	0 no change
Head tilt (L)	0	0 no change	0	0 no change
Head rotation (R)	0	0 no change	0	0 no change
Head rotation (L)	0	0 no change	0	0 no change
Foot pronation or supination (R)	2	2 no change	0	0 no change
Foot pronation or supination (L)	2	2 no change	0	0 no change
Toes point outward (R)	1	2 worsened	0	0 no change
Toes point outward (L)	1	2 worsened	0	0 no change

	Novice (n = 12)		Experienced (n = 4)	
Toes point inward (R)	0	0 no change	0	0 no change
Toes point inward (L)	0	0 no change	0	0 no change
Sagittal View				
Cervical protrusion	0	0 no change	0	0 no change
Forward head	4	3 improved	2	2 no change
Kyphosis	0	0 no change	0	0 no change
Lordosis	0	1 worsened	0	0 no change
Scapular protraction (R)	3	3 no change	1	2 worsened
Scapular protraction (L)	3	3 no change	1	2 worsened
Anterior pelvic tilt	4	4 no change	2	2 no change
Posterior pelvic tilt	3	0 improved	0	0 no change
Forward trunk lean	0	0 no change	1	1 no change
Posterior View				
Hyperextension of knee	2	3 worsened	0	0 no change
Elevated hip (R or L)	0	0 no change	0	0 no change

	Novice (n = 12)		Experienced (n = 4)	
Weight shift (R)	2	1 improved	0	1 worsened
Weight shift (L)	1	1 no change	0	0 no change

Table 3
Frequency of postural deviations during the dynamic NASM overhead squat test

	Novice (n = 12)		Experienced (n = 4)	
	Pre	**Post**	**Pre**	**Post**
Anterior View				
Foot turns outward (R)	1	2 worsened	0	0 no change
Foot turns outward (L)	0	1 worsened	0	0 no change
Knee turn inward (R)	5	5 no change	2	1 improved
Knee turn inward (L)	2	3 worsened	2	2 no change
Knee turn outward (R)	1	1 no change	1	0 improved
Knee turn outward (L)	1	0 improved	1	0 improved
Sagittal View				
Excessive forward lean	1	0 improved	1	1 no change
Low back arches	0	0 no change	0	0 no change
Low back rounds	0	0 no change	0	0 no change
Arms fall forward	3	7 worsened	2	0 improved
Forward head	2	0 improved	1	0 improved

	Novice (n = 12)		Experienced (n = 4)	
Shoulder elevation	0	0 no change	0	0 no change
Posterior View				
Foot flattens (R)	3	1 improved	0	0 no change
Foot flattens (L)	3	1 improved	0	0 no change
Heel rises (R)	0	0 no change	0	0 no change
Heel rises (L)	0	0 no change	0	0 no change
Weight shift to R	2	3 worsened	0	0 no change
Weight shift to L	0	0 no change	0	0 no change

In the experienced group, both static and dynamic postural assessment showed improved knee positioning. In static posture, scapular protraction and elevation of the right shoulder were more exaggerated after the intervention. Overall, the data show that experienced exercisers started the program with fewer postural deviations and had improvements in both static and dynamic posture after the intervention.

Discussion

Altogether, the results show that female cancer patients were able to improve their cardiorespiratory fitness, waist circumference, and flexibility as detected with a significant main effect of time. It is surprising that static balance was not significantly improved in novice exercisers, but was improved in the experienced group on their non-dominant foot. This improvement in balance occurred without concomitant gains in hamstring flexibility or lower body muscular strength. This is unexpected as hip-mobility is positively associated with balance in older adults [26] and previous studies showed that strength is associated with balance [1,27]. Differences in the study methodologies could account for these differences (i.e., different markers of flexibility or strength). Similarly, experienced exercisers showed a significant improvement in leftward excursion of their center of gravity during dynamic balance testing, representing enhanced dynamic balance in the non-dominant direction. The experienced exercise group fell in the 88th percentile at baseline, which allowed for greater gains in dynamic balance to be achieved. Whether improvements in balance would have been detected in the novice group if all exercise sessions had face-to-face exercise leadership is unknown.

Since significant improvements in balance were observed in the returning exercisers, this suggests that there may be a timeline of improvement associated with enhanced balance in this population. New exercisers had significant improvements in VO_2peak, muscular strength and hamstring flexibility, while these improvements were not significantly increased in returning exercises. This may indicate that balance development occurs after cardiorespiratory and muscular fitness gains. Also, the experienced exercisers accomplished a 45-second hold (which was the maximum time) during the baseline SLS test with visual feedback on both right and left feet, but this was not shown in the novice group. This suggests that patients may have required a baseline fitness to have significant gains in balance. Another possibility is that patients with ample exercise experience were able to achieve significant improvements in balance because they were knowledgeable about using proper training techniques. This may be especially important in the current study because one-half of the intervention was delivered virtually.

It is striking that significant improvements in balance and fitness were achieved with the virtual exercise intervention because a systemic review and meta-analysis showed that supervised training programs have superior effects on fitness and QOL compared to home-based regimens [28]. This approach is beneficial because it reduces staffing resources associated with the exercise intervention. In fact, providing patients with in-person training followed by independent exercise training may be an effective approach for enhancing balance in the cancer patient population, especially in individuals with exercise experience. Whether larger gains in balance could have been achieved with face-to-face exercise leadership for 12 weeks in experienced exercisers remains to be determined.

The observation that knee alignment during the NASM squat test worsened in the novice group suggests that this group may have benefitted from in-person training to ensure correct posture and alignment were used during exercise training. It is notable that in 2 of 3 novice exercises, there was a reduction of foot flattening during dynamic movement. Exercises targeting lower leg and feet musculature have been shown to improve medial longitudinal arch and balance [29], but in the current study this did not significantly impact balance. The experienced group, although comprised of a small sample, had consistent, positive lower body postural changes as a result of the intervention. However, upper body static posture did not have the same result. This suggests that the experienced group was capable of training with proper lower body posture, while additional oversight may have been beneficial when targeting upper body musculature. Still, results suggest that using a combination of in-person and virtual exercise programming may provide more postural benefit for the experienced exerciser when compared to an individual with little exercise experience. Overall, results of the current study correspond to findings that computer-feedback balance training improves balance outcomes in patients with CIPN [30], and aerobic, strength and sensorimotor training improves physical functioning and independence in patients with CIPN [31].

ADL require the use of multiple sensory inputs including visual, vestibular, and somatosensory systems; and when these systems are interrupted, they impair dynamic balance [6]. These systems are utilized more when performing dynamic balance assessments, whereas in static balance they are utilized to a lesser degree. Dynamic posture may be better suited to show direct implications on ADL and its related movements, such as rising from a chair and walking or performing manual tasks while standing [32]. Since static and dynamic balance are achieved through different sensory processes, both parameters should be taken into account when assessing balance.

Limitations

The main limitation in this study is due to pandemic-related events. Approximately 58% of the patients discontinued the program due to the mandatory quarantine and transition to a virtual exercise format. Patients withdrew because they felt they would benefit from an in-person program rather than a virtual intervention. Patients with reduced mobility sought in-person exercise training with specialized exercise equipment, and/or others felt that they could not be accountable for their exercise program. Thus, the patient population in the current study represents individuals who felt confident that they could independently complete the exercise intervention. The current study did not measure symptoms of CIPN; future research should quantify CIPN severity as it may be related to improvements in balance and posture. Even when faced with these limitations, significant improvements in balance were detected, indicating that the approach was effective in improving balance.

Analyzing postural data is difficult due to the qualitative and subject nature of the static and dynamic postural assessments. A lack of inter-rater reliability may have skewed the postural data. However, the identification of the presence or absence of a postural deviation minimized the subjective nature of the rating. A standardized and objective measure would improve future studies evaluating changes in posture. Additional work is necessary to validate the findings of the current study.

Conclusions

The intervention was effective in improving whole-body fitness in both novice and experienced groups. The experienced group had significant gains in static and dynamic balance and improved lower body posture. While the novice group had significant improvement in cardiorespiratory fitness and flexibility, they did not show significant improvements in balance.

Declarations

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Author's contribution:

[1] Participated in research design, writing of the paper, performance of the research, data analysis.

[2] Participated in research design, performance of the research

[3] Participated in research design, writing of the paper, performance of the research, data analysis

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 consent was 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.

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Figures

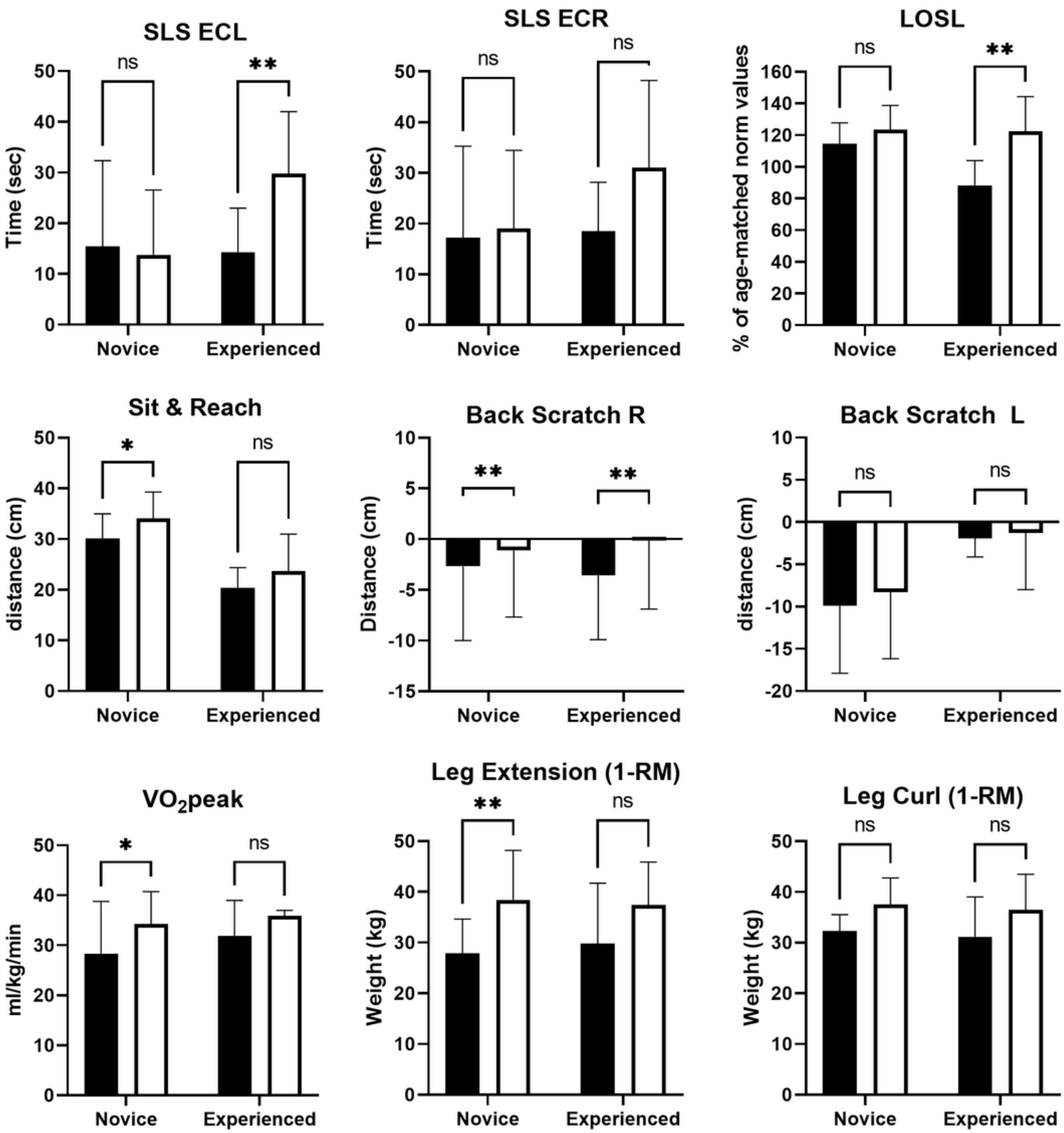

Figure 1

Fitness changes in novice and experienced exercisers prior to (black bars) and after the intervention (white bars), mean ± SD. Single leg stance (SLS), right (R), left (L), limits of stability (LOS), peak oxygen consumption (VO2peak), 1-repetition maximum (1-RM). Significant changes are detected with posthoc multiple comparison tests, *P<0.05, **P<0.01.