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Low intensity cycle ergometer exercise improve balance in breast cancer women underwent chemotherapy

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ABSTRACT

Background: Breast cancer is the most common type of malignancy affecting women and principal cause of cancer-associated deaths. Chemotherapy often induces side effects such as fatigue, neuropathy, and muscle weakness, which contribute to impaired balance and increased fall risk. This study aimed to investigate the impact of low-intensity cycle ergometer exercise on balance performance in breast cancer women underwent chemotherapy.

Methods: Randomized controlled trial with pretest–posttest design was conducted. Twenty-two eligible participants (aged 18–59 years, stage II–III breast cancer) were randomly assigned to treatment group (low-intensity cycling plus breathing exercises) or control group (breathing exercises only) for eight weeks. Balance was assessed using the Single Leg Stance (SLS) test, Short Physical Performance Battery (SPPB), and Activity-Specific Balance Confidence (ABC) scale. Data were analyzed using paired and independent t-tests or their non-parametric equivalents with a significance level of $p < 0.05$.

Results: The treatment group showed significant improvements in SLS ($p < 0.001$, d = 3.67), SPPB ($p = 0.003$, d = 0.475), and ABC scores ($p = 0.006$, d = 0.934). No significant differences were observed in the control group.

Conclusion: Low-intensity cycle ergometer exercise effectively enhances static and dynamic balance, functional performance, and confidence in women with breast cancer during chemotherapy, suggesting its suitability as a safe and beneficial component of rehabilitation protocols.

Keywords: aerobic exercise, breast neoplasms, chemotherapy good health and well-being, postural balance.

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INTRODUCTION

In Indonesia, breast cancer represents the most frequently diagnosed malignancy and continues to be a leading contributor to cancer-related mortality. Based on the Global Cancer Statistics (GLOBOCAN) 2020 data, breast cancer accounted for 2.3 million new cases (11.7%) worldwide, with a mortality rate of 6.9%.[1] Data from the Indonesian Ministry of Health (2020) recorded 65,858 new cases in that year. Chemotherapy impacts multiple physiological systems and is associated with adverse effects, including cancer-related cognitive impairment (CRCI), cancer-related fatigue (CRF), chemotherapy-induced peripheral neuropathy (CIPN), reduced muscle mass and strength, balance dysfunction, as well as acute complications such as nausea, vomiting, and diarrhea.[2] Study involving Medicare and Medicaid beneficiaries aged 65 years and above demonstrated a notably higher fall incidence among cancer patients undergoing chemotherapy (33%) compared with non-cancer patients (29%) Multiple factors have been recognized as influencing balance dysfunction and increasing the likelihood of falls, such as chemotherapy-induced peripheral neuropathy (CIPN), cancer-related fatigue (CRF), older age, lymphedema, and higher body mass index.[3,4] Han (2019) found that incorporating general exercise programs—comprising stretching, resistance, and core stabilization training—combined with slow abdominal breathing, had a direct beneficial effect on balance control.[5]

Recent evidence indicates that implementing structured exercise interventions during cancer treatment can reduce fatigue and pain, improve overall quality of life and physical performance, and help preserve muscle mass throughout systemic therapy. Specifically, aerobic training has been demonstrated to lessen cancer-related fatigue, enhance cardiovascular endurance, and reduce the negative side effects associated with chemotherapy.[6] A systematic review by Bula (2023) further reported that aerobic and resistance training significantly enhance both static and dynamic postural balance in women with breast cancer.[7] Aerobic training exerts positive neurophysiological effects by promoting axonal regeneration, inducing phenotypic adaptations in peripheral structures, and elevating neurotrophins concentrations. It also improves muscle function by stimulating protein synthesis, mitochondrial biogenesis, and enhancing type I muscle fiber strength and contraction velocity without hypertrophic changes, thereby contributing to improved balance.[8]

Although evidence supporting exercise interventions in oncology continues to expand, studies specifically examining balance outcomes in women with breast cancer undergoing chemotherapy remain limited, and a standardized or optimal exercise regimen has yet to be defined. Accordingly, this study was designed to investigate the impact of low-intensity cycle ergometer exercise on balance performance in this population.

METHODS

This study is randomized controlled trial obtained ethical clearance from the Health Research Ethics Committee with the number 0986/KEPK/V/2024. The study was carried out at the Medical Rehabilitation Unit from May to December 2024.

Eligible subject were women aged 18–59 years who had confirmed diagnosis by histopathology examination of stage II or III breast cancer and were receiving minimum of three cycles of intravenous chemotherapy at Dr. Soetomo General Academic Hospital. Additional inclusion criteria included: normal chest X-ray and echocardiographic findings within the preceding six months, with a left ventricular ejection fraction (LVEF) greater than 50%. Cognitive performance was verified to be within the normal range, as demonstrated by a Montreal Cognitive Assessment–Indonesian version (MoCA-INA) score of 26 or higher. Eligibility further required formal approval from the patient's attending physician and voluntary participation demonstrated through signed informed consent.

Exclusion criteria comprised any of the following: Exclusion criteria included the presence of hemodynamic instability (systolic blood pressure exceeding 160 mmHg, diastolic pressure above 100 mmHg, resting heart rate ≥120 beats per minute, oxygen saturation <95%, or body temperature >38°C) and significant hematological abnormalities (hemoglobin <10 g/dL, platelet count <50,000/µL or >450,000/µL, leukocyte count <4000/µL or >11,000/µL). Participants were also excluded if they presented with cardiac arrhythmias; pulmonary disorders; inability to stand or walk independently; visual, auditory, or vestibular impairments; lower limb neuropathy or polyneuropathy; joint deformities; or lower extremity pain rated >4 on the Visual Analogue Scale (VAS). Additional exclusion criteria comprised uncontrolled diabetes mellitus or hypertension, severe fatigue (Brief Fatigue Inventory score >36), engagement in a regular exercise program (2–3 sessions per week) prior to enrollment, and moderate-to-severe depression as indicated by a Hamilton Depression Rating Scale (HDRS) score >17.

Subject were withdrawn if they voluntarily discontinued participation, were unable to complete the exercise program (e.g., missing three consecutive sessions or attending <80% of sessions), developed new exclusionary medical conditions, passed away during the study, or explicitly declared withdrawal from the trial.

Subject meeting the inclusion criteria were identified through the Cancer Service and Development Center of Dr. Soetomo Hospital. Eligible candidates underwent an initial evaluation including medical history review, physical examination, depression and fatigue screening, cognitive testing, and assessment of laboratory results, echocardiography, and chest radiographs to ensure safety and eligibility. After obtaining oncologist approval and written informed consent, subject randomly allocated into either the treatment or control group by drawing lots.

All subject received thorough instruction regarding their assigned protocol and were asked to maintain a daily log documenting their physical activity, perceived symptoms, and dietary intake. Throughout the intervention period, both groups continued receiving standard oncological care and were advised to maintain routine daily activities while refraining from excessive exertion or prolonged exposure to heat. Unsupervised aerobic activities (e.g., jogging, swimming, cycling) were limited to a maximum of two 30-minute sessions per week. The overall intervention period lasted eight weeks and was tailored to each participant's health status. Balance function was evaluated in both the treatment and control groups before and after eight weeks of intervention using the Single Leg Stance (SLS) test, the Short Physical Performance Battery (SPPB), and the Activity-Specific Balance Confidence (ABC) Scale questionnaire.

Subject assigned to the treatment group followed a structured, physician-supervised exercise regimen twice weekly, consisting of home-based breathing exercises and low-intensity aerobic cycling combined with guided breathing sessions at the Medical Rehabilitation Unit. The program commenced before chemotherapy—either on the day of laboratory testing or one day before the third chemotherapy cycle, provided that the session fell between Wednesday and Friday. The second session was conducted five days after chemotherapy, with subsequent sessions scheduled according to individual chemotherapy timetables. Before each session, safety assessments (symptom evaluation and physical examination) were conducted. The target heart rate (THR) was determined using the formula THR = Resting Heart Rate + 30% of Heart Rate Reserve, and participants were instructed to sustain their perceived exertion within levels 11 to 12 on the Borg Rating of Perceived Exertion Scale. Each session lasted approximately 30 minutes, comprising a 5-minute warm-up, a 20-minute main aerobic component (which could be completed continuously or in two 10-minute bouts depending on tolerance), and a 5-minute cool-down. Subject were allowed to rest as needed, maintaining a maximum work-to-rest ratio of 1:1. If fatigue occurred within the first five minutes, the exercise was temporarily paused. Vital signs, oxygen saturation, and fatigue levels were continuously monitored before, during, and after each session to ensure participant safety.

Subject assigned to the control group performed home-based deep breathing exercises over an eight-week period. They were provided with a written guide explaining the technique, frequency, and schedule, and their adherence was monitored through daily telephone followups. The breathing exercise involved slow nasal inhalation followed by pursed-lip exhalation lasting approximately twice the duration of inhalation. Each session lasted three minutes and was repeated two to five times daily, with one hand placed on the abdomen to monitor diaphragmatic movement. Exercises could be performed while lying down, sitting, or standing, and subject were encouraged to practice during daily activities such as walking or climbing stairs.

Statistical analyses were performed using IBM SPSS Statistics version 26. Participant characteristics were summarized using descriptive measures, including central tendency, dispersion, and frequency distributions. Data distribution was evaluated through normality testing to guide the selection of parametric or non-parametric analyses. Within-group changes in balance outcomes before and after the intervention were examined using the paired t-test for normally distributed variables or the Wilcoxon Signed-Rank Test when normality assumptions were not met. Intergroup comparisons between the treatment and control groups were conducted using an independent t-test for normal data and the Mann–Whitney U Test when the normality assumption was not satisfied. The analytical procedure included comparing baseline balance function between the two groups; if no significant baseline difference was found, post-intervention balance scores were compared directly, whereas if a baseline difference existed, the difference scores (post–pre) were compared between groups. A significance level of $p < 0.05$ was applied for all tests.

RESULTS

A total of 24 subjects met the inclusion criteria and none of the exclusion criteria. The subjects were divided into two groups: 12 subjects received low-intensity cycle ergometer training and breathing exercises, and 12 subjects received breathing exercises. Two subjects dropped out by the end of the study. In the treatment group, one subject dropped out because they did not continue chemotherapy, while in the control group, one subject dropped out because they received additional radiotherapy. The baseline demographic and clinical characteristics of the participants are summarized in **Table 1**.

As shown in **Tables 2–4**, participants in the treatment group who performed low-intensity cycle ergometer training demonstrated significant improvements across all balance-related parameters compared with the control group. In the Single Leg Stance (SLS) test, the treatment group exhibited a substantial increase in balance duration for both the right and left legs following the intervention ($p < 0.001$ for each), with large effect sizes (Cohen's d = 3.67 and 3.61, respectively), whereas the control group showed no significant change. The Short Physical Performance Battery (SPPB) scores also improved significantly in the treatment group ($p = 0.003$), while no meaningful change was detected in the control group ($p = 0.58$). Similarly, the Activity-Specific Balance Confidence (ABC) scores increased markedly in the treatment group after the intervention ($p = 0.006$, d = 0.934), while the control group displayed no significant variation. Overall, these results indicate that low-intensity cycle ergometer exercise effectively enhanced both objective and self-perceived aspects of balance and functional ability among women with breast cancer undergoing chemotherapy.

DISCUSSION

The results of this study indicate that providing low-intensity cycle ergometer training for 8 weeks provided a significant increase in SLS, SPPB, and ABC Scale values. While providing breathing exercises did not provide a significant increase in SLS, SPPB, and ABC Scale values. SLS measurements on the right leg, the mean standing duration increased from 30.73 ± 6.32 seconds before the treatment to 67.27 ± 11.76 seconds after the treatment, with a change of +36.55 seconds ($p < 0.001$). For the left leg, the mean standing duration increased from 28.64 ± 5.94 seconds to 61.18 ± 12.51 seconds, with a change of 32.55 seconds ($p < 0.001$). Improvements of more than 30 seconds on both legs ($p < 0.001$) with a large effect size (Cohen's D = 3.67) on the right leg and left leg ($p < 0.000$) with a large effect size (Cohen's D = 3.61) for the SLS test indicate that cycle ergometer training significantly contributes to improving static balance. The results of this study align with those of Foley and Hasson (2016), who provided multicomponent training (aerobic, strengthening, and balance training) to women with breast cancer. Following a 12-week intervention period, participants demonstrated meaningful improvements, including a 24% increase in Single Leg Stance performance, an 18% enhancement in functional reach, and an 18% reduction in time on the Timed Up and Go test.

The mechanism of these improvements can be explained by the neuromuscular effects of aerobic exercise, which involve activating postural control through increased proprioception and strengthening of the core and lower limb muscles. Earlier investigations have indicated that performing aerobic exercise on a cycle ergometer can enhance vestibular and sensorimotor performance, thereby supporting greater postural stability.[8,9] Engaging in aerobic cycling activity promotes the upregulation of brain-derived neurotrophic factor (BDNF), a key mediator of neuroplasticity that assists in axonal repair and neural regeneration. Furthermore, exercise can also increase muscle mass. Exercise increases muscle metabolism, leading to increased muscle synthesis. Endurance-based exercise has been shown to enhance muscle fiber contractile efficiency by promoting angiogenesis, characterized by the expansion of capillary networks within skeletal muscle, thereby facilitating more effective delivery of oxygen and nutrients.[8]

Women with breast cancer experience fatigue due to the cancer and chemotherapy. Progressive cancer affects multiple organ systems and causes neurophysiological changes in the muscles. The production of inflammatory cytokines inhibits metabolism and normal muscle function. Fatigue affects balance function. The relationship between fatigue and balance dysfunction arises from the fact that balance regulation depends on central nervous system integration of sensory input from the vestibular, visual, and somatosensory pathways. When the musculature responsible for maintaining equilibrium becomes fatigued, these systems are disrupted, impairing postural control. Additionally, muscular fatigue

Table 1. Baseline demographic and clinical characteristics of the 22 patients

Characteristic	Control group (n=11)			Treatment group (n=11)			*P*-value[a]
	Min	Max	Mean ± SD	Min	Max	Mean ± SD	
Age (years)	40	59	50.54 ± 5.87	40	52	47.45 ± 3.64	0.15
Body weight (kg)	46.8	70.7	56.43 ± 8.04	34.9	72.6	56.82 ± 10.39	0.92
Body height (cm)	147	159	153.36 ± 4.24	142	158	151.18 ± 4.95	0.28
Body mass index (kg/m^2)	18.05	31.11	24.07 ± 3.80	16.15	29.39	24.88 ± 3.89	0.62
Commorbid (n; %)							
Hypertension	0			1 (9.1%)			
No commorbid	11 (100%)			10 (90.9%)			
Physical Activity Level based on International Physical Activity Questionnaire-Short Form (IPAQ-SF) (n, %)							
High	0			0			
Moderate	0			0			
Low	11 (100%)			11 (100%)			
Cancer Stage							
Stage 2	2 (18.2)			2 (18.2%)			
Stage 3	9 (81.8)			9 (81.8%)			
Starting exercise protocol							
After 3rd chemotherapy	5 (45%)			10 (90.9%)			
After 4th chemotherapy	1 (9.1%)			1 (9.1%)			

[a], independent t test
Cm, centimeter; kg, kilogram; m^2, meter squared; n, frequency; SD, standard deviation

Table 2. Analysis of the single leg stance test in both control and treatment groups

Single leg stance test	Control group Mean ± SD		Treatment group Mean ± SD		*P*-value[a]		Effect size (Cohen's *d*)	
	Right leg	Left leg	Right leg	Left leg	Right leg	Left leg	Right leg	Left leg
Pre-intervention	32.73 ± 6.10	27.45 ± 6.59	30.73 ± 6.32	28.64 ± 5.94	0.51	0.69	-	-
Post-intervention	32.00 ± 7.71	26.00 ± 5.71	67.27 ± 11.76	61.18 ± 12.51	<0.001	<0.001	3.67	3.61
P-value[b]	0.15	0.13	<0.001*	<0.001*	-	-	-	-

[a], independent T-test; [b], paired T-test
SD, standard deviation

Table 3. Analysis of the short physical performance battery in both control and treatment groups

Short physical performance battery	Control group			Treatment group			*P*-value[a]	Effect size (Cohen's *d*)
	Median	Q1	Q3	Median	Q1	Q3		
Pre-intervention	9.0	8.5	9.5	10.0	9.25	10.75	0.56	-
Post-intervention	9.0	8.5	9.5	12.0	11.25	12.75	0.01	0.475
P-value[b]		0.58			0.003			

[a], independent t test; [b], paired t test
Q, quartile.

may heighten muscle spindle discharge, altering afferent feedback to the central nervous system and consequently diminishing joint proprioception and kinesthetic accuracy, which adversely affects stability.[10]

Balance performance in this study was evaluated using the Short Physical Performance Battery (SPPB), which

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Table 4. Analysis of the activity-specific balance confidence in both control and treatment groups

Activity-specific balance confidence	Control group			Treatment group			*P*-value[a]	Effect size (Cohen's *d*)
	Median	Q1	Q3	Median	Q1	Q3		
Pre-intervention	98.13	95.94	100.32	95.00	91.87	98.13	0.23	-
Post-intervention	98.00	95.81	100.19	100.00	98.44	101.56	<0.001	0.934
P-value[b]		0.281			0.006			

[a], independent t test; [b], paired t test.
Q, quartile.

includes assessments of static balance (conducted in side-by-side, semi-tandem, and tandem standing positions), dynamic balance (time to rise from a chair five times), and gait speed.[2] The calculated effect size for the SPPB was statistically meaningful, whereas the control group showed no notable change. This elevation in scores reflects enhanced functional performance, including improved lower limb strength, dynamic balance, and transitional movement capability. These outcomes may be attributed to heightened neuromuscular efficiency and better motor coordination, consistent with the meta-analysis by Da Campo (2021) on aerobic cycle ergometer training.[11] That study explored the effects of aerobic exercise among older adults and individuals recovering from stroke, both of whom exhibited significant gains in functional capacity following interventions involving cycle ergometer exercise. A study conducted by Abbas (2022) divided three treatment groups into three groups: high-intensity functional training, cycle ergometer training, and a combination of both, administered for 12 weeks to patients with neurological disorders such as stroke and Parkinson's. They found improvements in balance and cognitive function in all three groups. Cycle ergometer training alone can improve balance and cognition. Balance is influenced by several body systems, including the exteroceptive, proprioceptive, visual, and vestibular sensory systems, central processing, and the motor system's response to adjust the body's balance to maintain balance.[12] Research by McGough (2016) demonstrated that a 10-week tandem cycling program, performed three times weekly by patients with Parkinson's disease, led to significant improvements in the Berg Balance Scale (BBS), Short Physical Performance Battery (SPPB), Five-Times Sit-to-Stand (5TSTS), and Timed Up and Go (TUG) scores.[13]

Analysis of the Activity-Specific Balance Confidence (ABC) Scale indicated a median improvement of 3.75 points ($p < 0.001$) in the intervention group, with an effect size of 0.934 based on the Rank-Biserial test. The result showed a significant treatment effect, while no meaningful change was observed in the control group. These results confirm that cycle ergometer-based training not only improves objective balance but also improves patients' perceptions of their balance in daily activities. Improvements in the ABC Scale may be linked to neuroplasticity mechanisms, where consistent aerobic exercise can increase patients' confidence in performing balance-requiring activities through improved postural control and body stabilization strategies.[8,9]

The outcomes of this research align with those reported in previous systematic reviews and meta-analyses by Luigi Da Campo (2021), which concluded that cycle ergometer training can improve balance and functional capacity. In this review, cycle ergometer training in chronic stroke patients resulted in significant improvements in balance and functional capacity, consistent with the results of this study. However, it's important to understand that the research in this systematic review was conducted on a group of patients with a history of stroke.[11]

A study by Marigold (2005) showed that a cycle ergometer-based exercise program combined with functional training resulted in significant improvements in dynamic balance.[14] However, some studies have found no significant effect on balance improvement, as reported by Lund (2018), who used a cycle ergometer but found no significant improvement in balance compared to a control group. This difference may be due to variations in intensity, duration, and sample characteristics in each study.[15]

During the treatment period, two cases of post-exercise muscle soreness occurred across all sessions. This muscle soreness was mild and tolerable without requiring additional medical treatment. No other significant side effects, such as injury or cardiovascular disorders, were observed. The outcomes of this research align with those reported in previous systematic reviews and meta-analyses. Research on the safety and side effects of exercise in cancer patients, particularly breast cancer, is still very limited. A systematic review and meta-analysis conducted by Thomsen (2023) regarding the dangers of exercise in cancer patients undergoing chemotherapy was inconclusive. This was due to a high risk of bias, poor reporting, and a lack of trials.[16]

Evidence from numerous randomized controlled trials, including both supervised and home-based exercise interventions, demonstrates that physical activity is generally safe for individuals with cancer, particularly those with breast cancer. Most studies report beneficial effects such as improved health status, enhanced physical function, and greater motivation to exercise, although these outcomes may not fully represent all cancer populations. According to the National Comprehensive Cancer Network (NCCN), individualized exercise or medical assessment is recommended to determine or adjust an appropriate exercise program.[6,17,18]

This study demonstrated that low-intensity cycle ergometer training can improve static balance, functional status, and balance self-confidence. The participants tolerated the low-intensity cycle ergometer program well, suggesting its potential as a feasible exercise approach for women receiving chemotherapy for breast cancer. Despite the observed improvements in balance and functional capacity, certain limitations should be acknowledged. The small sample size of only 22 participants limits the generalizability of the results.[19] The relatively short treatment duration may not be sufficient to evaluate the long-term impact of the treatment. The interpretation of the findings may have been influenced by potential participant-related bias, as individuals assigned to the intervention group may have exhibited higher levels of motivation compared to those in the control group.[20] To strengthen the evidence regarding the effectiveness of cycle ergometer-based training in improving balance and functional capacity, future research should consider studies with larger sample sizes to enhance external validity. Long-term evaluation is also needed to examine the impact of cycle ergometer training over longer periods (e.g., 6 months to 1 year) to assess the sustainability of the benefits. Combinations with other modalities, such as specific balance training, can also be studied to determine whether optimal results are achieved. In light of these results, this study reinforces the potential role of cycle ergometer training as an effective method for enhancing balance and functional performance in chemotherapy patients. Nonetheless, further investigations are warranted to refine the training protocol and clarify the physiological mechanisms involved.

CONCLUSION

The findings revealed that performing low-intensity cycling exercises significantly improved balance performance among women with breast cancer during chemotherapy treatment. Furthermore, subject who performed low-intensity cycling showed greater enhancement in balance compared to those who engaged in breathing exercises alone, indicating the superior efficacy of the cycling intervention in promoting postural stability. Consequently, incorporating low-intensity cycle ergometer exercise into rehabilitation programs for breast cancer patients undergoing chemotherapy may help enhance postural control and overall physical functioning.

ETHICAL CONSIDERATION

Ethical approval was obtained from the Health Research Ethics Committee of Dr. Soetomo General Academic Hospital, Surabaya, Indonesia (Approval No. 0986/KEPK/V/2024).

CONFLICT OF INTEREST

None

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AUTHOR CONTRIBUTIONS

J conceived the study design; J, A, DIS, DGAS, and M participated in data collection and analysis, drafting the manuscript, proofreading the manuscript, reviewing and editing the final version of the manuscript. All authors have agreed upon the sequence of authors for this manuscript.

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