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Impact of cycle ergometer based low-intensity aerobic exercise on quadriceps femoris strength in breast cancer patients receiving chemotherapy

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ABSTRACT

Background: Breast cancer and chemotherapy can reduce muscle strength through systemic and neuromusculoskeletal effects. This study aimed to evaluate the effect of low-intensity cycle ergometer exercise on quadriceps femoris strength in patients receiving chemotherapy.

Methods: A randomized controlled trial was conducted at the medical rehabilitation outpatient clinic, Dr. Soetomo General Academic Hospital, Surabaya, Indonesia, from May to November 2024. Twenty female patients aged 18–59 years with stage II–III breast cancer who had completed at least three chemotherapy cycles were enrolled. Eligible participants had normal echocardiography findings (left ventricular ejection fraction ≥ 50%) and oncologist approval. Exclusion criteria included hemodynamic instability, hematologic abnormalities, arrhythmia, pulmonary disease exacerbations, recent surgery or radiotherapy, severe pain, or cognitive disorders. Participants were randomly assigned to either an intervention group or a control group. The intervention group performed low-intensity cycle ergometer training twice weekly for eight, while the control group performed breathing exercises only. Quadriceps femoris strength was measured before and after the intervention using a handheld dynamometer. Data were analyzed using paired and independent *t*-tests, with significance set at *p*-value < 0.05.

Results: After eight weeks, the intervention group showed significantly greater increases in quadriceps femoris strength compared with the control group (right leg: $p = 0.006$; left leg: $p = 0.020$). Mean strength gains were 4.38 ± 2.3 kg (right) and 3.22 ± 1.9 kg (left), whereas the control group showed significant declines. Large effect sizes (Cohen's $d > 1$) indicated clinically meaningful improvements in the exercise group.

Conclusion: The intervention group showed significantly greater preservation and improvement of quadriceps femoris strength than the control group. Low-intensity cycle ergometer exercise appears to be a safe and effective rehabilitation strategy for maintaining muscle strength, functional capacity, and quality of life in breast cancer patients undergoing chemotherapy.

Keywords: aerobic exercise, breast cancer, chemotherapy, cycle ergometer, muscle strength, quadriceps femoris.

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INTRODUCTION

Muscle strength is a key determinant of functional independence and quality of life. Its decline may result from disease processes, complications, or treatment effects, leading to reduced physical activity and further muscle loss.[1] Similar mechanisms underlie muscle weakness across various chronic diseases, including breast cancer.[2]

Breast cancer is the most common cancer among women worldwide, representing about 12% of all new cases. In 2020, an estimated 2.3 million women were diagnosed and 685,000 died, while 7.8 million were living with the disease within five years of diagnosis, giving it the highest global prevalence.[3,4] This global trend is also reflected in Indonesia, where the age-standardized incidence declined from 19.1 per 100,000 in 2000 to 16.0 per 100,000 in 2019. Nearly all cases occur in women, with rates of 37.4 per 100,000 compared to only 0.4 per 100,000 in men—a disparity exceeding 100-fold.[5]

Breast cancer and its treatments can impair muscle strength both directly and indirectly. Pain, fatigue, and circadian rhythm disruption often reduce physical activity, while chemotherapy, radiotherapy, and hormone therapy contribute to weakness through mechanisms such as peripheral neuropathy, myopathy, and cardiotoxicity.[6,7] Anthracyclines are particularly associated with cardiotoxicity, whereas taxanes are linked to neuropathy.[8] These complications, combined with treatment-related fatigue, frequently lead to reduced activity, progressive deconditioning, and lower quality of life—a cycle well documented in survivorship literature.[9,10]

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Given these risks, interventions that preserve or improve muscle strength are essential for maintaining independence and quality of life in breast cancer patients undergoing chemotherapy. Low-intensity aerobic exercise is considered a safe and feasible rehabilitation strategy for this population. Therefore, this study aimed to evaluate the effect of low-intensity cycle ergometer–based aerobic exercise on quadriceps femoris strength in breast cancer patients receiving chemotherapy.

METHODS

This randomized controlled trial employed a two-group parallel design with pre- and post-test assessments. Ethical approval was obtained from the Health Research Ethics Committee of Dr. Soetomo General Academic Hospital, Surabaya, Indonesia (Ref: 0986/KEPK/V/2024). The study was conducted at the hospital's medical rehabilitation outpatient clinic from May to November 2024.

Inclusion criteria were female patients aged 18–59 years with histopathologically confirmed stage II–III breast cancer who had completed at least three cycles of intravenous chemotherapy at Dr. Soetomo General Academic Hospital. Eligible participants had normal chest X-ray and echocardiography results within six months, a left ventricular ejection fraction ≥50%, the ability to perform 30 minutes of low-intensity cycling, oncologist approval, and provided written informed consent. Exclusion criteria included hemodynamic instability (systolic blood pressure >160 mmHg, diastolic blood pressure >100 mmHg, pulse ≥120 bpm, oxygen saturation <95%, temperature >38 °C), hematological abnormalities (hemoglobin <10 g/dL, platelets <50,000 or >450,000/µL, leukocytes <4,000 or >11,000/µL), arrhythmias, pulmonary disease exacerbations, major joint limitations, lower limb pain >4/10, quadriceps strength below grade 3, prior radiotherapy, or surgery within the past month. Patients were also excluded if they had recently participated in structured aerobic exercise (≥2 sessions/week within two months), required assistive devices, had depression (Hamilton Depression Rating Scale score ≥17), or cognitive impairment (Montreal Cognitive Assessment–Indonesian version score <26). Dropout criteria included voluntary withdrawal, noncompliance (<80% attendance or >3 consecutive absences), new illness or injury meeting exclusion criteria, death, or explicit withdrawal from the study.

Eligible participants were identified through the hospital's Cancer Service and Development Center. Screening included review of medical history, physical and cognitive assessments, depression and fatigue scales, and evaluation of laboratory results, echocardiography, and chest X-rays to confirm eligibility and safety. Those meeting all criteria received oncologist approval, provided informed consent, and were randomly assigned by lot to either the intervention or control group. Participants were instructed on their respective protocols and asked to maintain a daily diary documenting physical activity, symptoms, and nutritional intake throughout the study.

The treatment group completed a physician-supervised exercise program for 8 weeks, twice weekly, combining home-based breathing exercises with low-intensity cycle-ergometer training and guided breathing sessions at the medical rehabilitation unit. The intervention began before chemotherapy, either on the day of laboratory screening or one day before the third cycle if scheduled between Wednesday and Friday. The second session occurred five days post-chemotherapy, with subsequent sessions aligned to the treatment schedule. Each session began with a safety check, including symptom review and physical examination. Target heart rate was set at resting heart rate + 30% of heart rate reserve, and exertion was maintained at Borg Scale levels 11–12 (interpreted as light to somewhat hard intensity). Sessions included a five-minute warm-up, 20 minutes of aerobic exercise (continuous or two 10-minute bouts), and a five-minute cool-down. Rest was permitted with a maximum work-to-rest ratio of 1:1, and sessions were paused if participants could not continue after five minutes. Vital signs, oxygen saturation, and fatigue were monitored throughout.

The control group performed home-based breathing exercises for eight weeks, guided by an informational pamphlet and monitored by daily telephone follow-up. The exercise involved slow nasal inhalation followed by pursed-lip exhalation at twice the duration of inhalation. Each session lasted three minutes, repeated two to five times daily, with participants placing one hand on the abdomen to monitor movement. The technique could be performed lying, sitting, or standing and was encouraged during daily activities such as walking or stair climbing.

Both groups continued standard oncological care at Dr. Soetomo General Academic Hospital. Participants were advised to maintain normal daily activities but avoid strenuous efforts such as long travel or prolonged heat exposure. Unsupervised aerobic activities (e.g., jogging, swimming, cycling) were limited to twice weekly for no longer than 30 minutes. The eight-week intervention was tailored to each participant's condition.

Quadriceps femoris strength was measured with a handheld dynamometer before and after the intervention. Low-cost digital devices have shown high validity and reliability for assessing isometric lower limb strength, making them practical alternatives to laboratory-grade equipment.[11] Data were analyzed using SPSS version 26.0. Between-group differences were assessed using independent *t*-tests or Mann–Whitney *U* tests, while within-group changes over eight weeks were assessed with paired *t*-tests or Wilcoxon signed-rank tests, depending on data distribution. Normality was tested with the Shapiro–Wilk test, and significance was set at p-value < 0.05.

RESULTS

A total of 21 female patients were enrolled and randomly assigned to the treatment

Table 1. Characteristics of study participants

Characteristic	Intervention (n=10) Mean±SD or n (%)	Control (n=10) Mean±SD or n (%)	*P*-value
Age, years	51.4 ± 5.967	47.1 ± 3.635	0.14
Cancer Stage			1.00
Stage II	2 (20%)	2 (20%)	
Stage III	8 (80%)	8 (80%)	
Chemotherapy Regiment			0.47
Anthracyclines + Alkylating	8 (80%)	10 (100%)	
Other	2 (20%)	0 (0%)	
Prescribed Ondansetron	10 (100%)	10 (100%)	1.00
Physical Activity Level (International Physical Activity Questionnaire-Short Form / IPAQ-SF)			1.00
Low	10 (100%)	10 (100%)	
Moderate	0 (0%)	0 (0%)	
High	0 (0%)	0 (0%)	
Body mass index, kg/m²			1.00
< 18.5	1 (10%)	1 (10%)	
18.5 - 22.9	1 (10%)	1 (10%)	
23.0 - 24.9	3 (30%)	3 (30%)	
25.0 - 29.9	5 (50%)	5 (50%)	
> 30	0 (0%)	0 (0%)	

n, frequency; kg/m², kilogram per meter squared; SD, standard deviation

Table 2. Comparison of quadriceps femoris muscle strength between the intervention (IG) and control (CG) groups

Quadriceps femoris muscle strength	Pre-test	Post-test	Paired T-test P-value (95% CI)	Effect size	Independent T-test *P*-value (95% CI)	Effect size
Right leg, kg						
IG	13.50 ± 3.09	17.88 ± 3.34	<0.001 (3.14- 5.63)	2.2	0.006 (-7.33 - -1.40)	1.3
CG	14.82 ± 2.83	13.52 ± 2.97	<0.001 (-1.49 - -1.12)	5.5		
Left Leg, kg						
IG	11.90 ± 2.54	15.12 ± 2.58	<0.001 (2.20 - 4.24)	2.5	0.020 (-5.900 - -0.572)	1.1
CG	13.18 ± 2.81	11.88 ± 3.07	<0.001 (-1.550 - -1.050)	3.7		

CI, confidence interval

group (n = 11) or control group (n = 10). One participant in the treatment group discontinued chemotherapy and was excluded, leaving 20 patients for analysis. Two participants in the treatment group experienced transient muscle pain after the first session, which resolved within 30–60 minutes, and no further adverse effects were reported. Baseline characteristics did not differ significantly between groups ($p > 0.05$). Table 1 presents the participants' overall characteristics.

Quadriceps femoris muscle strength outcomes are summarized in Table 2. After eight weeks, the treatment group showed significant bilateral improvements (right leg: $p < 0.001$, Cohen's $d = 2.2$; left leg: $p < 0.001$, Cohen's $d = 2.5$). In contrast, the control group demonstrated a significant decline (right leg: $p < 0.001$, Cohen's $d = 5.5$; left leg: $p < 0.001$, Cohen's $d = 3.7$). Between-group comparisons confirmed higher post-intervention strength in the treatment group compared with controls (right leg: $p = 0.006$, Cohen's $d = 1.3$; left leg: $p= 0.020$, Cohen's $d = 1.14$).

DISCUSSION

In this study, the average age of participants in the control group was 51.4 ± 5.97 years, while the treatment group averaged 47.1 ± 3.63 years, with no significant difference between them. The distribution of age and cancer stage was consistent with the general breast cancer prevalence, which most frequently affects women aged 46–55 years (34.9%) and is commonly diagnosed at stage III (56.6%).[9] Both groups also had similar nutritional status and cancer stage distributions, with 20% of subjects at stage II and 80% at stage III.

These characteristics align with previous research showing that nearly half of breast cancer patients undergoing chemotherapy present with advanced disease, particularly stage III (42%) and IV (31%).[10] Most participants in this study received a combination of anthracycline and alkylating agents, and all had completed more than three chemotherapy cycles. Their physical activity levels, measured by the International Physical Activity Questionnaire-Short Form (IPAQ-SF), were low due to chemotherapy-related lethargy, which usually appeared after the second round.

Fatigue and inactivity are common consequences of chemotherapy, leading to decreased functional capacity and reduced quality of life.[11] Independence in activities of daily living (ADL) is strongly linked to muscle strength, which depends on both muscle mass and performance capacity.[12] Weak muscle strength is associated with higher dependency in ADL and instrumental ADL (IADL), while adequate strength protects against functional decline.[1] Research by Wearing et al. (2019) identified quadriceps femoris strength as a strong and independent predictor of ADL performance.[13] In this study, baseline quadriceps strength was similar between groups, but after eight weeks, the treatment group showed significant increases in both right and left quadriceps strength ($p < 0.001$), while the control group declined. Specifically, right leg strength increased from 13.50 ± 3.09 kg to 17.88 ± 3.33 kg, and left leg strength from 11.90 ± 2.52 kg to 15.12 ± 2.58 kg in the treatment group, demonstrating that cycle ergometer training effectively improved muscle strength in breast cancer patients undergoing chemotherapy.

These findings are consistent with previous studies reporting that breast cancer patients tend to experience generalized weakness, proprioceptive disturbances, and reduced strength in both upper and lower limbs.[14] Chemotherapy contributes to muscle weakness primarily through oxidative stress, which disrupts redox signaling and control.[15,16] Agents such as cyclophosphamide and anthracyclines generate reactive oxygen species (ROS) and reduce antioxidant defenses, leading to mitochondrial dysfunction, decreased ATP production, and impaired contractile proteins such as actin and myosin.[17] Alkylating agents also exacerbate muscle toxicity by reducing mitochondrial viability and increasing oxidative burden, resulting in muscle wasting and reduced performance.[18-20] Persistent oxidative stress and sarcopenia in cancer patients have been linked to higher chemotherapy toxicity, hospitalization rates, and mortality.[12]

Exercise interrupts this cycle by enhancing mitochondrial efficiency and improving oxygen delivery and utilization.[19-21] Low-intensity aerobic training, such as cycling, improves adaptation in type I (slow-twitch) muscle fibers, which are high in mitochondria and capillaries, resulting in improved fatigue resistance and endurance.[22] It promotes mitochondrial biogenesis and muscular growth by increasing the expression of PGC-1α.[22] Additionally, endurance exercise raises the lactate threshold, improves oxidative enzyme activity, and enhances peripheral circulation, which collectively increase muscular endurance and delay fatigue.[23,24] These physiological mechanisms explain the significant improvement in quadriceps femoris strength observed in the exercise group.

Beyond muscle-level adaptations, aerobic exercise also exerts systemic effects by modulating inflammatory cytokines and increasing antioxidant capacity, counteracting chemotherapy-induced oxidative stress and preserving muscle integrity.[22,25] These responses not only enhance physical performance but may also help mitigate fatigue and improve overall quality of life in cancer patients.

Despite these promising results, several limitations should be noted. This was a preliminary study with a small sample size, single-center design, short intervention duration, and low-intensity protocol (30% HRR, twice weekly). Nutritional factors—such as protein and caloric intake—were not controlled and may have influenced the outcomes. Furthermore, the absence of biochemical or imaging biomarkers (e.g., oxidative stress markers, electromyography, or muscle mass imaging) limits the mechanistic interpretation of the results. Additionally, controlling dietary intake and assessing nutritional status may help reduce potential confounding factors influencing muscle strength outcomes. Future studies should employ larger and more diverse cohorts, longer interventions, and multimodal exercise programs that combine aerobic and resistance training. Incorporating biochemical and functional biomarkers will provide deeper insights into the physiological adaptations to exercise and its role in improving muscle strength, metabolic health, and long-term quality of life among breast cancer patients undergoing chemotherapy.

CONCLUSION

Low-intensity cycle-ergometer exercise is a safe and effective strategy to strengthen the quadriceps femoris, support functional capacity, and improve quality of life in breast cancer patients undergoing chemotherapy. Future research should involve more diverse populations, longer interventions, and varied exercise regimens to clarify long-term benefits. Incorporating nutritional support, addressing confounding factors, and emphasizing proper warm-up may further optimize outcomes and minimize adverse effects.

ETHICAL CLEARANCE

The Health Research Ethics Committee of Dr. Soetomo General Academic Hospital in Surabaya, Indonesia, approved the study (Approval No. 0986/KEPK/V/2024).

CONFLICT OF INTEREST

The authors have declared no conflicts of interest.

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AUTHOR CONTRIBUTION

DCP, ILD, BAU, and DGAS developed the study design and established the intellectual content. All authors participated in the literature search, data collecting, and clinical and experimental trials. DCP, ILD, DAU, and DGAS collected data and conducted statistical analysis. All authors contributed to manuscript preparation and editing, and ILD served as the study's guarantor.

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