

Mitigating cardiovascular risk: the effect of low-intensity cycle-ergometer training on appendicular muscle mass and hypertension-related factors in breast cancer patients undergoing chemotherapy

Mitigación del riesgo cardiovascular: El efecto del entrenamiento en cicloergómetro de baja intensidad sobre la masa muscular apendicular y los factores relacionados con la hipertensión en pacientes con cáncer de mama sometidas a quimioterapia

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Abstract

Breast cancer survivors face a dual burden: chemotherapy-induced muscle wasting (sarcopenia) and increased long-term cardiovascular risk, including hypertension. This study evaluated whether a low-intensity aerobic exercise intervention could mitigate muscle loss and potentially influence hypertension-related physiological factors. In a randomized controlled trial, 22 breast cancer patients undergoing chemotherapy were allocated to an intervention group (n=11) or a control group (n=11). The intervention group completed an 8-week, twice-weekly program of supervised cycle-ergometer training at low intensity (30% heart rate reserve), while the control group performed breathing exercises. Appendicular Skeletal Muscle Mass Index (ASMI) was measured via Bioelectrical Impedance Analysis; blood pressure and heart rate were monitored as secondary safety and exploratory measures. Twenty participants completed the study. The exercise group showed a significant increase in ASMI (from 15.62 ± 1.50 kg/m² to 17.15 ± 2.26 kg/m², p=0.004), while the

control group experienced a significant decrease (from 15.14 ± 1.69 kg/m² to 14.34 ± 1.49 kg/m², p=0.001). The between-group difference post-intervention was highly significant (p=0.004) with a large effect size (Cohen's d=1.47). Minor, non-clinical increases in blood pressure were observed in both groups, remaining within safe limits. The intervention was safe, with a 1.25% adverse event rate. Conclusion: Supervised, low-intensity cycle training effectively counteracts chemotherapy-induced muscle loss. By preserving metabolically active muscle mass, this practical intervention may serve as a foundational strategy in a holistic care model aimed at concurrently addressing sarcopenia and modifiable cardiovascular risk factors, such as hypertension, in breast cancer patients.

Keywords: Hypertension, Cardiovascular Risk, Breast Cancer, Chemotherapy, Aerobic Exercise, Sarcopenia, Muscle Mass.

Las sobrevivientes de cáncer de mama se enfrentan a una doble carga: la pérdida muscular inducida por la quimioterapia (sarcopenia) y un mayor riesgo cardiovascular a largo plazo, incluyendo la hipertensión. Este estudio evaluó si una intervención de ejercicio aeróbico de baja intensidad podría mitigar la pérdida muscular y potencialmente influir en los factores fisiológicos relacionados con la hipertensión. En un ensayo controlado aleatorizado, 22 pacientes con cáncer de mama sometidas a quimioterapia fueron asignadas a un grupo de intervención (n = 11) o a un grupo control (n = 11). El grupo de intervención completó un programa de 8 semanas, dos veces por semana, de entrenamiento supervisado en cicloergómetro a baja intensidad (30 % de reserva de frecuencia cardíaca), mientras que el grupo control realizó ejercicios de respiración. El índice de masa muscular esquelética apendicular (IMSA) se midió mediante análisis de impedancia bioeléctrica; se monitorizaron la presión arterial y la frecuencia cardíaca como medidas secundarias de seguridad y exploratorias. Veinte participantes completaron el estudio. El grupo de ejercicio mostró un aumento significativo en ASMI (de $15,62 \pm 1,50 \text{ kg/m}^2$ a $17,15 \pm 2,26 \text{ kg/m}^2$, $p=0,004$), mientras que el grupo control experimentó una disminución significativa (de $15,14 \pm 1,69 \text{ kg/m}^2$ a $14,34 \pm 1,49 \text{ kg/m}^2$, $p=0,001$). La diferencia entre grupos después de la intervención fue altamente significativa ($p=0,004$) con un gran tamaño del efecto (d de Cohen= $1,47$). Se observaron aumentos menores, no clínicos, en la presión arterial en ambos grupos, que permanecieron dentro de límites seguros. La intervención fue segura, con una tasa de eventos adversos del 1,25%. Conclusión: El entrenamiento en bicicleta supervisado de baja intensidad contrarresta eficazmente la pérdida muscular inducida por la quimioterapia. Al preservar la masa muscular metabólicamente activa, esta intervención práctica puede servir como estrategia fundamental en un modelo de atención holística dirigido a abordar simultáneamente la sarcopenia y los factores de riesgo cardiovascular modificables, como la hipertensión, en pacientes con cáncer de mama.

Palabras clave: Hipertensión, Riesgo cardiovascular, Cáncer de mama, Quimioterapia, Ejercicio aeróbico, Sarcopenia, Masa muscular

Breast cancer remains a critical global health challenge, representing the second leading cause of death worldwide, surpassed only by cardiovascular diseases¹. This is particularly evident in Indonesia, where it is the primary cause of cancer-related mortality among women, with nearly 22,000 deaths reported in 2020 alongside a high incidence of new cases^{2,3}. Advances in early detection and treatment have improved survival rates; however, the long-term management of survivors is complicated by the adverse effects of therapies such as chemotherapy⁴. These include a well-documented spectrum of side effects ranging from cancer-related fatigue and neuropathy to more systemic issues like cardiotoxicity and significant alterations in body composition, notably the loss of skeletal muscle mass⁵.

The decline in muscle mass, or sarcopenia, during cancer treatment is a multifactorial problem. It results from a combination of reduced physical activity, systemic inflammation, metabolic dysregulation, and the direct toxic effects of chemotherapy⁶. This loss impairs fundamental physical capacities such as strength, endurance, and balance, creating a vicious cycle of decreasing functional capacity, increased sedentary behavior, and diminished quality of life⁷⁻⁹. Critically, skeletal muscle is not merely an organ of locomotion; it is a vital metabolic and endocrine tissue. Its wasting is linked to poorer metabolic health, insulin resistance, and may exacerbate underlying cardiovascular risk factors, such as hypertension, which are already of concern in an aging population and can be adversely affected by certain cancer treatments¹⁰. Therefore, preserving appendicular skeletal muscle mass, commonly assessed via the Appendicular Skeletal Muscle Mass Index (ASMI), is essential not only for physical function but also for overall metabolic and cardiovascular health in survivors¹¹.

Within this context, physical exercise emerges as a potent, non-pharmacological countermeasure. Aerobic exercise, in particular, is recommended for its systemic benefits, which include improving cardiorespiratory fitness, reducing systemic inflammation, and enhancing metabolic profiles—all of which are relevant for mitigating cardiovascular risk¹². However, the practical application of exercise in breast cancer patients undergoing chemotherapy, especially in resource-limited settings, requires careful consideration of safety, feasibility, and efficacy. While tools like Bioelectrical Impedance Analysis (BIA) offer a practical method for monitoring body composition changes like ASMI, research defining optimal, safe, and accessible exercise protocols in this population remains scarce^{13,14}.

Specifically, there is a gap in evidence regarding the ef-

fects of structured, low-intensity aerobic modalities, such as cycle ergometry, on preserving or improving muscle mass during active chemotherapy. Such interventions could serve a dual purpose: combating treatment-induced sarcopenia and potentially contributing to better cardiovascular risk profiles. This study, therefore, aimed to investigate the effect of a supervised, low-intensity cycle-ergometer training program on the ASMI of breast cancer patients undergoing chemotherapy at Dr. Soetomo General Hospital, Surabaya, Indonesia. The findings seek to inform safer, practical rehabilitation strategies that address the intertwined challenges of musculoskeletal and cardiovascular health in oncology care.

Study Design and Participants

This study employed a pretest-posttest randomized controlled trial design to evaluate the efficacy of a structured exercise intervention. The intervention group underwent an 8-week supervised aerobic training program using a cycle ergometer, while the control group received standard care, which included breathing exercises but no structured aerobic training. The primary outcome was the change in Appendicular Skeletal Muscle Mass Index (ASMI), assessed via Bioelectrical Impedance Analysis (BIA).

The study was conducted at the Department of Medical Rehabilitation, Dr. Soetomo General Hospital, Surabaya, from February 2024 onwards. The target population consisted of female breast cancer patients actively receiving intravenous chemotherapy at the hospital's oncology clinic. Participants were eligible if they met the following criteria: (1) a histopathologically confirmed diagnosis of unilateral or bilateral breast cancer, stage II or III; (2) currently undergoing at least three cycles of outpatient chemotherapy; (3) aged between 18 and 59 years; (4) possessed normal cognitive function; (5) obtained medical clearance from their treating oncologist; and (6) were physically capable of completing 30 minutes of low-intensity cycling. All participants provided written informed consent after a detailed explanation of the study protocol. The study received ethical approval from the Institutional Review Board of Dr. Soetomo General Hospital.

Sample Size and Randomization

The sample size was estimated based on a previous study by Battaglini et al. (2007), targeting a total of 22 participants to achieve adequate statistical power¹⁵. A consecutive sampling method was used for recruitment. Once eligible patients were identified and consented, they were randomly allocated to either the intervention group (n=11) or the control group (n=11) using a simple lottery system to ensure unbiased group assignment.

Intervention Protocol

The exercise intervention was designed to be safe, feasible, and of low-to-moderate intensity for patients

undergoing chemotherapy. The intervention group participated in supervised cycle-ergometer sessions twice weekly for 8 weeks (16 sessions total). Each 30-minute session was structured as follows:

Warm-up: 5 minutes of very light pedaling without resistance.

Main Exercise: 20 minutes of continuous cycling at a low intensity. The target intensity was set at **30% of Heart Rate Reserve (HRR)** or a rating of perceived exertion (RPE) of 11-12 on the Borg scale. The workload was individually adjusted, starting from 15 watts and progressively increasing to a maximum of 35 watts as tolerated, while maintaining a cadence of 40-50 revolutions per minute (RPM).

Cool-down: 5 minutes of light pedaling and stretching.

Exercise sessions were directly supervised by a trained physiotherapist to ensure correct technique, monitor for adverse events, and adjust intensity as needed. Adherence to the session schedule was recorded.

Control Group Protocol

Participants in the control group did not receive the structured aerobic exercise intervention. They continued with their standard medical care, which included a routine regimen of breathing exercises often prescribed for pulmonary hygiene. This design allowed for the isolation of the effect of the aerobic cycling intervention compared to standard care without added aerobic training.

Outcome Measurement

The primary outcome, Appendicular Skeletal Muscle Mass (ASM), was calculated using a validated multi-frequency Bioelectrical Impedance Analysis (BIA) device. Measurements were taken under standardized conditions (fasting state, empty bladder, no strenuous prior activity) at two time points: **baseline (pre-intervention)** and **immediately after the 8-week intervention period (post-intervention)**. The ASMI was then derived by dividing the ASM (in kilograms) by the square of height (in meters²). Secondary observations included monitoring of vital signs (heart rate, blood pressure) before and after selected sessions and systematic recording of any adverse events.

Statistical Analysis

Data analysis was performed using statistical software. Normality of data distribution was assessed using the Shapiro-Wilk test. For within-group comparisons of pre- and post-intervention ASMI values, paired sample t-tests were used. For between-group comparisons of post-intervention outcomes, independent sample t-tests were employed. The magnitude of the intervention effect was calculated using Cohen's d. A p-value of less than 0.05 was considered statistically significant.

This randomized controlled trial was conducted at Dr. Soetomo General Hospital, Surabaya, from May to December 2024, following ethical approval (Certificate No. 0986/KEPK/V/2024). Initially, 22 women with breast cancer undergoing chemotherapy were enrolled and randomly allocated into two groups. One participant from the intervention group discontinued due to cessation of chemotherapy, and one from the control group withdrew after initiating radiotherapy. Consequently, **20 participants (10 per group)** completed the full 8-week protocol and were included in the final per-protocol analysis. All participants reported low levels of physical activity at baseline according to the International Physical Activity Questionnaire (IPAQ).

Baseline demographic and clinical characteristics were comparable between the two groups (Table 1). The mean age was 47.5 ± 3.8 years in the intervention group and 51.2 ± 5.8 years in the control group. Most participants in both groups had stage III breast cancer (80%). Vital signs, including resting heart rate and blood pressure, were similar at baseline. Notably, baseline systolic and diastolic blood pressure values were within normal to high-normal ranges across both groups.

Table 1. Baseline Demographic and Clinical Characteristics of Participants

Characteristic	Intervention Group (n=10)	Control Group (n=10)
Age (years), Mean \pm SD	47.5 ± 3.8	51.2 ± 5.8
Weight Pre (kg), Mean \pm SD	59.0 ± 7.8	56.9 ± 8.3
Height (cm), Mean \pm SD	151.6 ± 5.0	153.6 ± 4.4
BMI (kg/m ²), Mean \pm SD	25.8 ± 2.7	24.2 ± 3.9
Resting HR Pre (bpm), Mean \pm SD	84.2 ± 3.3	84.2 ± 3.2
SBP Pre (mmHg), Mean \pm SD	118.6 ± 15.0	120.4 ± 3.7
DBP Pre (mmHg), Mean \pm SD	75.1 ± 8.3	79.1 ± 8.3
Cancer Stage III, n (%)	8 (80%)	8 (80%)
Low Physical Activity (IPAQ), n (%)	10 (100%)	10 (100%)
Anthracycline-based Regimen, n (%)	10 (100%)	8 (80%)

Primary Outcome: Changes in Appendicular Skeletal Muscle Index (ASMI)

Data for ASMI were normally distributed (Shapiro-Wilk $p > 0.05$). The analysis revealed divergent trajectories for the two groups.

In the **control group**, which received only breathing exercises, a statistically significant decrease in ASMI was observed after the 8-week period, from 15.14 ± 1.69 kg/m² to 14.34 ± 1.49 kg/m² ($p = 0.001$).

Conversely, the **intervention group**, which performed the cycle-ergometer training, demonstrated a significant increase in ASMI, from 15.62 ± 1.50 kg/m² to 17.15 ± 2.26 kg/m² ($p = 0.004$).

Table 2. Within-Group Changes in Appendicular Skeletal Muscle Index (ASMI)

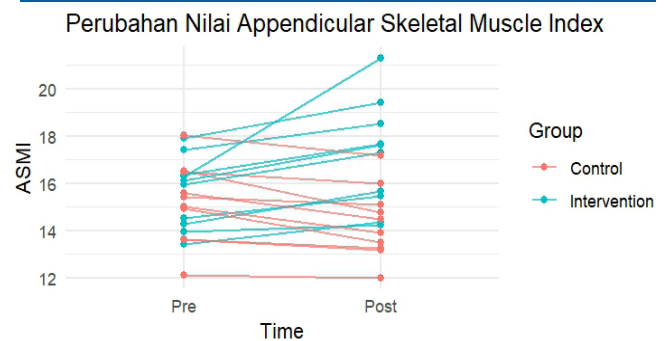
Group	ASMI Pre-Intervention, Mean \pm SD (kg/m ²)	ASMI Post-Intervention, Mean \pm SD (kg/m ²)	p-value
Control (n=10)	15.14 ± 1.69	14.34 ± 1.49	0.001
Intervention (n=10)	15.62 ± 1.50	17.15 ± 2.26	0.004

At baseline, there was no significant difference in ASMI between the groups ($p = 0.51$). After the intervention, the between-group difference was highly significant. The mean post-intervention ASMI in the intervention group (17.15 ± 2.26 kg/m²) was substantially higher than in the control group (14.34 ± 1.49 kg/m²), with a p-value of 0.004. The effect size of the intervention, calculated using Cohen's d, was 1.47, indicating a **very large clinical effect**.

Table 3. Between-Group Comparison of Appendicular Skeletal Muscle Index (ASMI)

Measurement	Control Group, Mean \pm SD (kg/m ²)	Intervention Group, Mean \pm SD (kg/m ²)	p-value (Between Groups)	Cohen's d
Pre-Intervention	15.14 ± 1.69	15.62 ± 1.50	0.51	-
Post-Intervention	14.34 ± 1.49	17.15 ± 2.26	0.004	1.47

Figure 1. Changes in Appendicular Skeletal Muscle Index (ASMI) from Baseline to Post-Intervention



Post-intervention vital signs were monitored as a safety measure. Small, non-clinically significant increases were noted in resting heart rate and blood pressure in both groups, with slightly greater increases observed in the intervention group (Table 4). These changes remained within safe physiological limits expected during exercise adaptation.

Table 4. Pre- and Post-Intervention Vital Signs

Vital Sign	Intervention Group (Mean ± SD)	Control Group (Mean ± SD)
Heart Rate (bpm)	Pre: 84.2 ± 3.3	Pre: 84.2 ± 3.2
	Post: 86.2 ± 4.8	Post: 85.4 ± 2.2
Systolic BP (mmHg)	Pre: 118.6 ± 15.0	Pre: 120.4 ± 3.7
	Post: 123.0 ± 16.6	Post: 122.6 ± 3.3
Diastolic BP (mmHg)	Pre: 75.1 ± 8.3	Pre: 79.1 ± 8.3
	Post: 77.8 ± 9.6	Post: 81.3 ± 7.0

The intervention proved to be safe and well-tolerated. Over the total of 160 exercise sessions, only two mild adverse events were recorded, both instances of delayed onset muscle soreness (DOMS) in the intervention group (1.25% incidence rate). Symptoms were managed promptly per protocol and resolved within an hour.

Discussion

The principal finding of this randomized controlled trial is that a supervised, 8-week program of low-intensity cycle-ergometer training effectively increased the Appendicular Skeletal Muscle Mass Index (ASMI) in breast cancer patients undergoing chemotherapy, whereas a significant decrease was observed in the control group receiving only standard care. The between-group difference was substantial, with a large effect size (Cohen's $d = 1.47$), underscoring the clinical relevance of this accessible exercise modality. These results align with the growing body of evidence supporting the integration of structured physical activity into oncology care to combat treatment-induced sarcopenia¹⁶.

The decline in ASMI within the control group mirrors the expected trajectory of cancer-related muscle wasting, driven by a confluence of chemotherapy toxicity, systemic inflammation, anabolic resistance, and reduced physical activity¹⁷. In stark contrast, the intervention group's improvement demonstrates that even low-intensity aerobic exercise can provide a potent anabolic stimulus during a physiologically challenging period. The prescribed intensity and progressive overload likely stimulated positive physiological adaptations. This is consistent with research showing aerobic exercise can influence inflammatory pathways and metabolic efficiency, which are often dysregulated during chemotherapy^{18,19}.

The exercise program demonstrated an excellent safety profile, with a very low incidence (1.25%) of transient, mild musculoskeletal discomfort (DOMS) and no serious adverse events. This reinforces the feasibility of implementing similar protocols in clinical settings, even for patients with low baseline activity levels and those managing the side effects of treatment. When contex-

tualized within the broader literature, our findings on ASMI improvement are consistent with studies demonstrating the benefits of exercise for body composition in cancer survivors^{20,21}. The notable effect size in our relatively short-term study highlights the potential efficacy of supervised, low-intensity cycling as a practical starting point for rehabilitation.

Study Limitations and Future Directions

Several limitations must be acknowledged. The sample size was modest, and the study followed a per-protocol analysis. The 8-week duration, while showing significant effects, is insufficient to assess long-term sustainability. Body composition was assessed via BIA, which, though practical, is influenced by hydration status. Furthermore, the study did not include measures of cardiovascular function or metabolic markers. These limitations chart a course for future research. Larger, longer-term trials are warranted. Subsequent studies should employ gold-standard body composition analysis and incorporate additional health outcome measures to better understand the systemic benefits of such exercise interventions during cancer treatment.

Conclusions

This study provides robust evidence that low-intensity, supervised cycle-ergometer training is a safe and effective intervention for attenuating chemotherapy-induced muscle loss in breast cancer patients, leading to a significant increase in appendicular skeletal muscle mass compared to standard care. From a translational perspective, these findings advocate for the systematic integration of such supervised aerobic exercise programs into the supportive care regimen for patients undergoing active chemotherapy. This approach serves the primary purpose of preserving physical function and mitigating a major side effect of treatment. Future research should build upon this foundation by investigating the long-term impact of such exercise interventions on comprehensive health outcomes in the growing population of breast cancer survivors, to optimize survivorship care protocols.

References

1. Siegel RL, Miller KD, Wagle NS, Jemal A. Cancer statistics, 2023. *CA Cancer J Clin.* 2023;73(1):17-48. <https://doi.org/10.3322/caac.21763>
2. Global Cancer Observatory. Indonesia Fact Sheets: Breast Cancer. International Agency for Research on Cancer; 2020. Accessed [Date]. <https://gco.iarc.fr/today/data/factsheets/populations/360->

3. Sung H, Ferlay J, Siegel RL, et al. Global Cancer Statistics 2020: GLOBOCAN Estimates of Incidence and Mortality Worldwide for 36 Cancers in 185 Countries. *CA Cancer J Clin.* 2021;71(3):209-249. <https://doi.org/10.3322/caac.21660>
4. Giaquinto AN, Sung H, Miller KD, et al. Breast Cancer Statistics, 2022. *CA Cancer J Clin.* 2022;72(6):524-541. <https://doi.org/10.3322/caac.21754>
5. Doherty J, Davison J, McLaughlin M, et al. Prevalence, knowledge, and factors associated with e-cigarette use among parents of secondary school children. *Public Health Pract (Oxf).* 2022;4:100334. <https://doi.org/10.1016/j.puhip.2022.100334>
6. Aartolahti E, Lönnroos E, Hartikainen S, Häkkinen A. Long-term strength and balance training in the prevention of decline in muscle strength and mobility in older adults. *Aging Clin Exp Res.* 2020;32(1):59-66. <https://doi.org/10.1007/s40520-019-01161-2>
7. Demir A. The Effect of Exergames on Sedentary University Students' shoulder And Knee Proprioception Sense. *International Journal of Education Technology and Scientific Research.* 2020;5(12):657-676.
8. Corrado B, Giardulli B, Costa M. Evidence-based practice in rehabilitation of myasthenia gravis. A systematic review of literature. *J Funct Morphol Kinesiol.* 2020;5(4):71. <https://doi.org/10.3390/jfkm5040071>
9. Dempsey PC, Matthews CE, Dashti SG, et al. Sedentary behavior and chronic disease: mechanisms and future directions. *J Phys Act Health.* 2020;17(1):52-61. <https://doi.org/10.1123/jpah.2019-0377>
10. Wu M, Wei Y, Lv J, et al. Associations of muscle mass, strength, and quality with all-cause mortality in China: a population-based cohort study. *Chin Med J (Engl).* 2022;135(11):1358-1368. <https://doi.org/10.1097/CM9.0000000000002100>
11. Sergi G, De Rui M, Stubbs B, Veronese N, Manzato E. Measurement of lean body mass using bioelectrical impedance analysis: a consideration of the pros and cons. *Aging Clin Exp Res.* 2017;29(4):591-597. <https://doi.org/10.1007/s40520-016-0622-6>
12. Ahmad Ruzaidi DA, Mahat MM, Shafiee SA, et al. Advocating electrically conductive scaffolds with low immunogenicity for biomedical applications: a review. *Polymers (Basel).* 2021;13(19):3395. <https://doi.org/10.3390/polym13193395>
13. Battaglini CL, Mihalik JP, Bottaro M, et al. Effect of exercise on the caloric intake of breast cancer patients undergoing treatment. *Braz J Med Biol Res.* 2008;41(8):709-715. <https://doi.org/10.1590/s0100-879x2008000800011>
14. Irwin ML, Alvarez-Reeves M, Cadmus L, et al. Exercise improves body fat, lean mass, and bone mass in breast cancer survivors. *Obesity (Silver Spring).* 2009;17(8):1534-1541. <https://doi.org/10.1038/oby.2009.18>
15. Karlsson Linnér R, Mallard TT, Barr PB, et al. Multivariate analysis of 1.5 million people identifies genetic associations with traits related to self-regulation and addiction. *Nat Neurosci.* 2021;24(10):1367-1376. <https://doi.org/10.1038/s41593-021-00908-3>
16. Krause M, Rodrigues-Krause J, O'Hagan C, et al. The effects of aerobic exercise training at two different intensities in obesity and type 2 diabetes: implications for oxidative stress, low-grade inflammation, and nitric oxide production. *Eur J Appl Physiol.* 2014;114(2):251-260. <https://doi.org/10.1007/s00421-013-2769-6>
17. Wilk M, Zajac A, Tufano JJ. The influence of movement tempo during resistance training on muscular strength and hypertrophy responses: a review. *Sports Med.* 2021;51(8):1629-1650. <https://doi.org/10.1007/s40279-021-01465-2>
18. França-Lara ÉG, Weber SH, Pinho RA, Casali-da-Rocha JC, Elifio-Esposito S. A remote, fully oriented, personalized program of physical exercise for women in follow-up after breast cancer treatment improves body composition and physical fitness. *Sports Med Health Sci.* 2023;5(2):128-136. <https://doi.org/10.1016/j.smhs.2023.03.003>
19. Roberts MD, Romero MA, Mobley CB, et al. Skeletal muscle mitochondrial volume and myozenin-1 protein differences exist between high and low anabolic responders to resistance training. *PeerJ.* 2018;6:e5338. <https://doi.org/10.7717/peerj.5338>
20. Agnew M. Improving the physical function and quality of life of adults living with advanced cancer: the role of physical activity [dissertation]. The University of Wisconsin-Madison; 2023.
21. Benamati A. Postural monitoring and neuromuscular synergies related to damage due to a sedentary lifestyle. [Source/Journal Info Needed]. 2025.
22. Iwamoto T, et al. Long-Term Physical Activity and Body Composition After Exercise and Educational Programs for Breast Cancer: A Randomized Controlled Trial From the Setouchi Breast Project-10. *Clin Breast Cancer.* 2024;24(1):27-35.e8. <https://doi.org/10.1016/j.clbc.2023.10.005>