UDC 613.73:616.12-008.46:616-092
DOI https://doi.org/10.63181/ujcvs.2025.33(4).184-191

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# Comparative Effects of 12 Weeks of Center-Based versus Home-Based Exercise Training on hs-CRP and IL-6 Levels in Patients with Heart Failure Reduced Ejection Fraction

**Abstract**

**Introduction.** Heart failure (HF) is a global health concern characterized by significant morbidity and mortality, often associated with chronic systemic inflammation. Exercise-based cardiac rehabilitation is a cornerstone of HF management; however, accessibility limitations often restrict participation. Home-based exercise programs offer a potentially viable alternative. This study aimed to evaluate the effects of 12 weeks of center-based versus home-based exercise training on inflammatory markers, specifically high-sensitivity C-reactive protein (hs-CRP) and interleukin-6 (IL-6), in patients with heart failure with reduced ejection fraction.

**Aim.** This study aimed to evaluate the effects of 12 weeks of center-based versus home-based exercise training on inflammatory markers, specifically high-sensitivity C-reactive protein (hs-CRP) and interleukin-6 (IL-6), in patients with heart failure reduced ejection fraction.

**Materials and Methods.** A quasi-experimental design was employed involving 31 patients diagnosed with heart failure with left ventricular ejection fraction below 40 %. Participants were allocated into two groups: center-based exercise (n=15) and home-based exercise (n=16). Both groups underwent a 12-week exercise rehabilitation program consisting of light-intensity sessions five times per week. Baseline and post-intervention blood samples were collected to measure serum levels of hs-CRP and IL-6. Clinical and demographic data were also recorded. Statistical analyses were performed using the Mann–Whitney and Wilcoxon signed-rank tests, with significance set at p<0.05.

**Results and Discussion.** Both exercise modalities resulted in significant reductions in IL-6 and hs-CRP levels after 12 weeks (p<0.001). Median IL-6 decreased from 13.1 pg/mL to 4.8 pg/mL, while median hs-CRP declined from 4.3 mg/L to 2.5 mg/L across all participants. No statistically significant differences were observed between the center-based and home-based groups in the extent of reduction for either biomarker (IL-6, p=0.906; hs-CRP, p=0.200).

**Conclusions.** Twelve weeks of home-based exercise training is as effective as center-based training in reducing systemic inflammation, as measured by IL-6 and hs-CRP, in patients with heart failure with reduced ejection fraction. These findings support the use of home-based rehabilitation as a viable alternative to center-based programs for managing inflammation in this patient population.

***Keywords:*** *cardiac rehabilitation, inflammatory markers, HFrEF, cytokines, ambulatory care*

**Introduction.** Heart failure (HF) is a non-communicable disease with a significant global prevalence and burden. According to the World Health Organization (WHO), almost nine million individuals worldwide are living with heart failure, contributing substantially to the global cardiovascular disease mortality rate of 17.31 million, which accounts for 48 % of all non-communicable disease deaths. Of these cardiovascular deaths, 7.3 million are attributed specifically to heart failure [1]. Similarly, in Indonesia, the prevalence of heart failure is estimated to exceed five hundred thousand individuals. The mortality rate associated with congestive heart failure (CHF) varies by disease severity, ranging from 5-10 % annually in mild cases to 30-40 % in severe cases [2]. In the United States, the prevalence of heart failure has reached approximately 5.7 million individuals, with projections estimating an increase to 8 million by 2030. In Southeast Asia, prevalence rates range from 6.7 % in Malaysia to 4.5 % in Singapore, affecting a total of 9 million people across the region [1]. Data from Indonesia's Basic Health Research in 2013 indicate that CHF accounted for about 9.7 % of all cardiac diseases, with the highest prevalence reported in East Nusa Tenggara (0.8 %), followed by Central Sulawesi (0.7 %), and South Sulawesi and Papua at about 0.5 %.

Congestive heart failure is a clinical syndrome characterized by structural and/or functional cardiac abnormalities that result in decreased perfusion of vital organs. The primary goals of managing CHF are to improve patients' functional capacity and quality of life while reducing mortality [3]. Cardiac rehabilitation is defined as a multidisciplinary intervention aimed at restoring physical, psychological, and social functioning after acute cardiac events or chronic cardiovascular conditions, such as heart failure. It has been demonstrated that cardiac rehabilitation leads to improvements in exercise capacity and quality of life, as well as a reduction in complications and mortality in patients with these conditions [3,4].

Despite its proven benefits, cardiac rehabilitation remains underutilized in clinical practice, with participation rates among heart failure patients ranging from 14 % to 43 % globally and high attrition rates after enrollment. Barriers to participation include patient-related factors, healthcare professional limitations, and systemic issues within medical services [3]. Furthermore, accessibility to hospital-based rehabilitation can be limited by geographical, financial, and health-status constraints. To address these challenges, home-based exercise programs supported by modern information and communication technologies have emerged as viable alternatives. Regular monitoring during outpatient visits has been shown to improve adherence and overcome barriers to home-based cardiac rehabilitation [5].

Patients with heart failure exhibit impaired cardiac pump function, which leads to skeletal muscle alterations and endothelial dysfunction. Elevated levels of pro-inflammatory cytokines, particularly interleukin-6 (IL-6), have been identified in heart failure patients and correlate with impaired left ventricular function and adverse prognosis, especially in idiopathic dilated cardiomyopathy [6]. IL-6 has been demonstrated to be a long-term predictor of mortality over a 12-month follow-up period, independent of peak oxygen uptake ($VO_2$peak) and left ventricular ejection fraction [7].

C-reactive protein (CRP) is a liver-derived marker of inflammation that responds to inflammatory cytokines such as IL-1, IL-6, and TNF-α. Elevated CRP levels have been implicated in the pathogenesis of cardiovascular disease and heart failure, contributing to endothelial dysfunction through the downregulation of nitric oxide production and promoting thrombus formation, thereby increasing cardiovascular risk. High-sensitivity CRP (hsCRP) assays can detect very low CRP levels, with values above 0.3 mg/L indicating an increased risk of heart failure. Notably, hsCRP levels below 2 mg/L are associated with reduced cardiovascular events over a two-year period [6].

Exercise-based cardiac rehabilitation has been shown to reduce hsCRP levels in patients with coronary heart disease. For instance, supervised exercise therapy for six weeks followed by eight weeks of home-based exercise significantly decreased hsCRP levels [8,9]. However, some studies, such as one involving chronic heart failure patients undergoing high- versus low-intensity inspiratory muscle training over 10 weeks, found no significant changes in TNF-α, IL-6, CRP, or apoptosis markers [10].

This study aims to further elucidate the role of inflammation in heart failure and evaluate the effects of 12 weeks of center-based and home-based exercise training on hsCRP and IL-6 levels in patients with heart failure reduced ejection fraction. Understanding these inflammatory changes may provide valuable insights for future therapeutic strategies targeting heart failure.

**Materials and Methods**

*Study design and patient selection*

This study employed a quasi-experimental design, with data collected before and after patients underwent either center-based or home-based exercise rehabilitation programs. The research was conducted at the Integrated Cardiac Center of Dr. Wahidin Sudirohusodo Hospital, Makassar, beginning in September 2022 and continuing until the required sample size was achieved.

Participants were recruited according to predefined inclusion and exclusion criteria. Inclusion criteria required patients to be aged 18 to 70 years, exhibit reduced left ventricular systolic function with an ejection fraction below 40% and be classified as New York Heart Association (NYHA) functional class I or II. Exclusion criteria encompassed recent acute coronary syndrome (within 40 days), percutaneous angioplasty in the past two weeks, coronary artery bypass graft surgery within three months, presence of intracardiac thrombus, resting heart rate above 90 beats per minute, conduction abnormalities or exercise-induced arrhythmias, acute myocarditis or pericarditis, congenital or valvular heart disease necessitating surgery, hypertrophic cardiomyopathy, severe pulmonary disease, anemia (hemoglobin <11.0 g/dL), significant musculoskeletal or neurological disabilities, recent embolism or thrombophlebitis, acute or chronic non-cardiac illnesses such as thyrotoxicosis, renal failure, or uncontrolled diabetes, active malignancy, aortic aneurysm, severe psychiatric disorders, and refusal to participate. Participants were classified as dropouts if their adherence to the exercise regimen was below 80 % or if they declined to attend the six-week follow-up.

*Research protocol*

Eligible participants were provided with detailed explanations about the study and asked to provide informed consent prior to enrollment. Baseline demographic data, including date of birth and gender, were obtained from patient identification documents. Additional information regarding education level, occupation, income, medical history, and current medications was collected through patient interviews. Clinical assessments included measurements of weight, height, body mass index, resting heart rate, blood pressure, and NYHA classification, all derived from physical examinations. Echocardiographic evaluation of right ventricular systolic function was performed using a GE Vivid E95 ultrasound system.

Venous blood samples were collected on the first day before initiation of the exercise program and on the final day of the 12-week intervention. Samples were placed into EDTA tubes for subsequent analysis. Participants were randomly assigned to either the center-based exercise group or the home-based exercise group. All subjects underwent baseline assessments and were referred to the Medical Rehabilitation Department's Cardiorespiratory Subdivision for evaluation of exercise eligibility. This evaluation included a submaximal exercise test utilizing the six-minute walk test and peak flowmeter assessment, as well as psychological consultation. Functional capacity was estimated by calculating $VO_2$ max from the distance covered during the six-minute walk test.

All participants received standardized cardiac rehabilitation education covering medication adherence, stress management, risk factor modification including smoking cessation and healthy dietary practices and physical exercise. Both groups were provided with exercise kits containing 1 kg dumbbells, an incentive spirometer, a digital sphygmomanometer, a pulse oximeter, a logbook, and a flash drive containing instructional cardiac exercise videos and educational materials. The exercise regimen consisted of light-intensity sessions conducted five times per week for 30 minutes each, over a 12-week period. The initial two sessions (one week) were supervised by the cardiac rehabilitation team at the Integrated Cardiac Center of Wahidin Sudirohusodo Hospital.

Following this, the center-based exercise group continued the program with two supervised sessions per week at the hospital and three independent sessions at home using the provided exercise kit, maintaining a total of five sessions weekly for 12 weeks. The home-based exercise group performed all sessions at home, with two remote supervision sessions by the rehabilitation team and three independent sessions weekly. Participants recorded exercise adherence and activities in the logbook, which was reviewed regularly. Follow-up laboratory evaluations were conducted on the final day of the 12-week program.

*Statistical analysis*

Data analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 21. Continuous variables, including age, blood pressure, mean arterial pressure, body mass index, body surface area, echocardiographic parameters, and levels of hs-CRP and IL-6, were presented as means with standard deviations. Categorical variables such as gender, occupation, education level, and economic status were expressed as frequencies. Statistical significance was determined at a p-value threshold of less than 0.05. The results were reported narratively and supplemented with tables and figures as appropriate.

Ethical approval for the study was obtained from the Health Research Ethics Commission of the Faculty of Medicine, Hasanuddin University Makassar, under recommendation number 365/UN4.6.4.5.31/PP36/2025, protocol number UH25050352.

**Results.** A total of 31 participants met the inclusion and exclusion criteria and were enrolled in the study. The sample was divided into two groups: the center-based exercise group (n=15) and the home-based exercise group (n=16).

Table 1 presents the baseline characteristics of the study subjects in both groups. The mean age of participants in the center-based exercise group was significantly higher at 61.13±6.30 years compared to 54.94±8.73 years in the home-based exercise group (p=0.032). Regarding gender distribution, all participants in the center-based group were male (100 %), whereas the home-based exercise group comprised 18.8 % females and 81.3 % males; this difference was not statistically significant (p=0.078). Occupationally, the majority of subjects in the center-based group were retired (46.7 %), while the home-based group displayed a more varied distribution, with the largest proportion employed in the private sector (31.3 %). No significant difference was observed between groups in terms of occupation (p=0.334).

Educational attainment was similar across groups, with most participants having attained university-level education (60.0 % in the center-based group versus 50.0 % in the home-based group; p=0.808). Economic status also did not differ significantly, with the majority of participants classified in the low-income category (<Rp. 5,000,000 per month), accounting for 86.7 % in the center-based group and 68.8 % in the home-based group (p=0.311).

Clinical characteristics are summarized in Table 2. The mean systolic blood pressure was slightly lower in the center-based exercise group (120.67±20.40 mmHg) compared to the home-based group (125.50±20.11 mmHg), although this difference was not statistically significant (p=0.512). Diastolic blood pressure was comparable

**Table 1**

*Study characteristics*

| Variables | Center-based exercise (n=15) | Home-based exercise (n=16) | Total (n=31) | p-value |
|---|---|---|---|---|
| **Age (years)** | 61.13±6.30 | 54.94±8.73 | 56.2±8.3 | 0.032 |
| **Gender** | | | | 0.078 |
| Female | 0 (0.0) | 3 (18.8) | 3 (9.7) | |
| Male | 15 (100.0) | 13 (81.3) | 28 (90.3) | |
| **Occupation** | | | | 0.334 |
| Entrepreuner | 5 (33.3) | 5 (31.3) | 10 (32.3) | |
| Civil servants | 1 (6.7) | 5 (31.3) | 6 (19.4) | |
| Housewives | 1 (6.7) | 2 (12.5) | 3 (9.7) | |
| Farmers/Labours | 1 (6.7) | 1 (6.3) | 2 (6.5) | |
| Retirees | 7 (46.7) | 3 (18.8) | 10 (32.3) | |
| **Education level** | | | | 0.808 |
| Low (Primary/Junior High School) | 2 (13.3) | 2 (12.5) | 4 (12.9) | |
| Middle (Senior High School) | 4 (26.7) | 6 (37.5) | 10 (32.3) | |
| High (University) | 9 (60.0) | 8 (50.0) | 17 (54.8) | |
| **Economic level (income per month)** | | | | 0.311 |
| Low (<Rp. 5.000.000) | 13 (86.7) | 11 (68.8) | 24 (77.4) | |
| Middle (Rp. 5.000.000-10.000.000) | 2 (13.3) | 3 (18.8) | 5 (16.1) | |
| High (>Rp. 10.000.000) | 0 (0.0) | 2 (12.5) | 2 (6.5) | |

*Notes:* *Values are n (%) or mean±SD, unless stated otherwise. Continuous variables were compared using independent-samples t-test, categorical variables with Pearson Chi-square test. Non-normally distributed data were analyzed with Mann-Whitney U test and presented as median

between groups (75.13±13.36 mmHg vs. 75.00±12.52 mmHg; p=0.977). The majority of participants in the center-based group were normotensive (80.0 %) relative to 62.5 % in the home-based group, while the prevalence of grade I hypertension was higher in the home-based group (37.5 % vs. 20.0 %), with no significant difference (p=0.283). Mean arterial pressure was similar between groups (90.31±15.10 mmHg vs. 89.58±18.66 mmHg; p=0.906). Body mass index (BMI) values indicated a range from normal weight to grade I obesity in both groups (23.71±2.55 kg/m$^2$ in the center-based group and 24.58±1.74 kg/m$^2$ in the home-based group; p=0.271). The proportions of normal weight and grade I obesity were also comparable (66.7 % vs. 62.5 % and 33.3 % vs. 37.5 %, respectively; p=0.809). Body surface area did not differ significantly between groups (1.71±0.16 m$^2$ vs. 1.72±0.13 m$^2$; p=0.915).

Baseline inflammatory markers before the intervention are detailed in Table 3. The median IL-6 level in the home-based exercise group was 11.8 pg/mL

**Table 2**

*Baseline clinical characteristics and therapies received by patients*

| Variables | Center-based exercise (n=15) | Home-based exercise (n=16) | Total (n=31) | p-value |
|---|---|---|---|---|
| **Sistolic BP (mmHg)** | 120.67±20.40 | 125.50±20.11 | 123.13±20.21 | 0.512 |
| **Diastolic BP (mmHg)** | 75.13±13.36 | 75.00±12.52 | 75.06±12.86 | 0.977 |
| Normal | 12 (80.0) | 10 (62.5) | 22 (71.0) | 0.283 |
| Hypertension I | 3 (20.0) | 6 (37.5) | 9 (29.0) | |
| **MAP (mmHg)** | 90.31±15.10 | 89.58±18.66 | 89.94±16.88 | 0.906 |
| **BMI (kg/m²)** | 23.71±2.55 | 24.58±1.74 | 24.17±2.19 | 0.271 |
| Normal | 10 (66.7) | 10 (62.5) | 20 (64.5) | 0.809 |
| Obesity I | 5 (33.3) | 6 (37.5) | 11 (35.5) | |
| **BSA (m²)** | 1.71±0.16 | 1.72±0.13 | 1.71±0.14 | 0.915 |

*Notes*: *Values are n (%) or mean ± SD, unless stated otherwise. Continuous variables were compared using independent-samples t-test, categorical variables with Pearson Chi-square test. Non-normally distributed data were analyzed with Mann-Whitney U test and presented as median.

(range 2.0-26.8), while the center-based group exhibited a median of 17.4 pg/mL (range 2.0-34.9). The overall median IL-6 level was 13.1 pg/mL (range 2.0-34.9). Statistical analysis revealed no significant difference between groups (p=0.268). Similarly, median hs-CRP levels were 4.7 mg/L (range 2.5-13.7) in the home-based group and 3.2 mg/L (range 2.5-19.7) in the center-based group, with an overall median of 4.3 mg/L (range 2.5-19.7). No statistically significant difference was observed between groups (p=0.873).

Post-exercise levels of IL-6 and hs-CRP are presented in Table 4. The median IL-6 level decreased to 4.6 pg/mL (range 2.0-22.4) in the home-based group and to 5.5 pg/mL (range 2.0-22.9) in the center-based group, with an overall median of 4.8 pg/mL (range 2.0-22.9). No significant difference was found between groups following the intervention (p=0.546). Both groups exhibited a median hs-CRP level of 2.5 mg/L post-intervention, with ranges of 2.5-8.6 mg/L and 2.5-17.3 mg/L in the home-based and center-based groups, respectively. Statistical analysis confirmed no significant difference between groups (p=0.644).

The comparison of changes (Δ) in IL-6 and hs-CRP levels after the intervention is summarized in Table 5. The median reduction in IL-6 was -3.8 pg/mL (range -12.1 to 1.8) in the home-based group and -3.9 pg/mL (range -30.5 to 0.0) in the center-based group, with an overall median decrease of -3.9 pg/mL (range -30.5 to 1.8). No significant difference in IL-6 changes was observed between groups (p=0.906). For hs-CRP, the home-based group demonstrated a median decrease of -1.3 mg/L (range -11.2 to 0.0), while the center-based group showed a reduction of -0.4 mg/L (range -4.7 to 0.0). The overall median change was -0.7 mg/L (range -11.2 to 0.0), with no statistically significant difference between groups (p=0.200).

Further analysis compares IL-6 and hs-CRP levels pre- and post-exercise. The median IL-6 level significantly decreased from 13.1 pg/mL (range 2.0-34.9) pre-exercise to 4.8 pg/mL (range 2.0-22.9) post-exercise (p<0.001, Wilcoxon signed-rank test). Similarly, hs-CRP levels showed a significant reduction from a median of 4.3 mg/L (range 2.5-19.7) before the intervention to 2.5 mg/L (range 2.5-17.3) after the intervention (p<0.001).

When analyzed by exercise modality, the home-based exercise group exhibited a significant decrease in median IL-6 from 11.8 pg/mL (range 2.0-26.8) pre-exercise to 4.6 pg/mL (range 2.0-22.4) post-exercise (p=0.001). The center-based exercise group also showed a significant reduction in IL-6 levels from 17.4 pg/mL (range 2.0-34.9) to 5.5 pg/mL (range 2.0-22.9) (p=0.002).

Similarly, hs-CRP levels significantly decreased in both groups. The home-based exercise group's median hs-CRP level declined from 4.7 mg/L (range 2.5-13.7)

**Table 3**

*Pre-exercise IL-6 and HS-CRP Levels*

| Variables | Home-based exercise (n=16) | Center-based exercise (n=15) | Total (n=31) | p-value |
|---|---|---|---|---|
| IL-6 (pg/mL) | 11.8 (2.0-26.8) | 17.4 (2.0-34.9) | 13.1 (2.0-34.9) | 0.268 |
| HS-CRP (mg/L) | 4.7 (2.5-13.7) | 3.2 (2.5-19.7) | 4.3 (2.5-19.7) | 0.873 |

*Notes*: *Mann-Whitney test.

**Table 4**

*Post-exercise IL-6 and HS-CRP Levels*

| Variables | Home-based exercise (n=16) | Center-based exercise (n=15) | Total (n=31) | p-value |
|---|---|---|---|---|
| IL-6 (pg/mL) | 4.6 (2-22.4) | 5.5 (2-22.9) | 4.8 (2-22.9) | 0.546 |
| HS-CRP (mg/L) | 2.5 (2.5-8.6) | 2.5 (2.5-17.3) | 2.5 (2.5-17.3) | 0.644 |

*Notes*: *Mann-Whitney test.

**Table 5**

*Comparison of Changes in IL-6 and HS-CRP Levels Post-exercise*

| Variables | Home-based exercise (n=16) | Center-based exercise (n=15) | Total (n=31) | p-value |
|---|---|---|---|---|
| Δ IL-6 (pg/mL) | -3.8 ((-12.1)-1.8) | -3.9 ((-30.5)-0.0) | -3.9 ((-30.5)-1.8) | 0.906 |
| Δ HS-CRP (mg/L) | -1.3 ((-11.2)-0.0) | -0.4((-4.7)-0.0) | -0.7 ((-11.2)-0.0) | 0.200 |

*Notes*: *Mann-Whitney test.

to 2.5 mg/L (range 2.5-8.6) (p=0.002), while the center-based exercise group's median hs-CRP decreased from 3.2 mg/L (range 2.5-19.7) to 2.5 mg/L (range 2.5-17.3) (p=0.005).

**Discussion.** This quasi-experimental study aimed to evaluate the effectiveness of a 12-week home-based physical exercise program, "Gammara' Jantungku", in patients with heart failure and reduced ejection fraction. Thirty-one participants were enrolled, with comparable demographic and clinical characteristics between the two groups. Fifteen participants underwent center-based exercise, while sixteen followed the home-based exercise program. Consistent with previous literature, the majority of participants were male, with only three females opting for the home-based program. This gender disparity aligns with findings by Grace et al. [11], who reported that women's participation in cardiac rehabilitation remains substantially lower than men's, with only 11-20 % of women in the US and Canada attending such programs despite guideline recommendations. Smith et al. [12] further identified barriers to female participation, including transportation difficulties, household responsibilities, concerns about exercise-induced fatigue and pain, and insufficient family or partner support.

Although the difference in mean age between the home-based group (54.9±8.7 years) and the center-based group (61.13±6.3 years) was not statistically significant, it may reflect lifestyle factors, such as work commitments, influencing preference for home-based programs. This observation is consistent with prior studies reporting no significant age differences between home- and center-based cardiac rehabilitation participants [13,14].

Pharmacological management across both groups demonstrated similar patterns, with spironolactone being the most commonly prescribed medication, followed by antiplatelets, statins, and renin–angiotensin system (RAS) blockers. These therapeutic regimens align with current clinical guidelines emphasizing the use of aldosterone receptor antagonists, RAS blockers, and beta-blockers as foundational treatments for heart failure [15].

Our findings revealed a significant reduction in interleukin-6 (IL-6) levels following 12 weeks of exercise intervention in both groups. This aligns with the meta-analysis by Malandish et al. [16], which demonstrated that physical exercise significantly reduces IL-6 levels without significant heterogeneity. Similarly, Kourek et al. [17] observed decreased IL-6 levels in chronic heart failure patients after cardiac rehabilitation, with reductions noted irrespective of baseline functional capacity.

High-sensitivity C-reactive protein (hs-CRP) levels also decreased post-intervention significantly in both groups. This finding concurs with Malandish et al. [16], who reported a significant reduction in hs-CRP following exercise (SMD = -0.441; 95 % CI: -0.642 to -0.240; p=0.001), despite notable heterogeneity. Milani et al. [8] similarly documented significant decreases in hs-CRP among patients undergoing cardiac rehabilitation, independent of statin therapy or weight loss. Another study further corroborated these results in patients post-coronary artery bypass graft surgery, where hs-CRP levels significantly declined only in the rehabilitation group [18].

Heart failure is characterized by heightened systemic inflammation, involving proinflammatory cytokines and endothelial activation, which contribute to disease progression and adverse outcomes [19,20]. Exercise-induced physiological adaptations may attenuate the production of inflammatory mediators such as IL-6 and hs-CRP, thereby modulating vascular adhesion molecules (VAMs), including ICAM and VCAM in cardiomyocytes and fibroblasts [19,21]. The anti-inflammatory effects observed in this study likely reflect suppression of pathological mechanisms driven by renin-angiotensin-aldosterone system activation and sympathetic nervous system hyperactivity in heart failure [16,19,21].

Importantly, no significant differences were observed between center-based and home-based exercise programs in reducing IL-6 and hs-CRP levels. To our knowledge, this study is among the first to directly compare these two modalities regarding inflammatory marker outcomes. These findings are consistent with a recent systematic review, which included 24 trials with 3,046 participants and found no significant differences between home-based and center-based cardiac rehabilitation in terms of mortality, exercise capacity, quality of life, program completion rates, or costs up to 12 months of follow-up [20]. This evidence supports the comparable effectiveness of both rehabilitation approaches in improving clinical outcomes for patients with myocardial infarction, revascularization, or heart failure.

This study has several limitations. The relatively small sample size limits the generalizability of the findings, warranting larger-scale studies to validate these results. Additionally, challenges related to internet connectivity quality impeded optimal monitoring during home-based exercise sessions. Variability in participants' communication devices (e.g., mobile phones, laptops, televisions) also affected the consistency and quality of remote exercise interactions. Future research should involve larger cohorts and longer intervention periods to better elucidate the sustained effects of home-based exercise on clinical and inflammatory outcomes in heart failure patients. Standardizing communication technology and ensuring reliable internet access will enhance remote supervision and participant engagement, potentially improving rehabilitation adherence and outcomes.

**Conclusion.** In conclusion, this study demonstrates that a 12-week home-based exercise program is not inferior to a center-based program in reducing inflammatory markers, specifically IL-6 and hs-CRP, in patients with heart failure and reduced ejection fraction. Both exercise modalities yielded statistically significant reductions in these biomarkers, underscoring the anti-inflammatory benefits of structured physical activity in this population. These findings provide novel evidence supporting the equivalence of home-based and center-based cardiac rehabilitation in modulating systemic inflammation.

**Final Statements**

**Prospects for Further Research.** Future research should validate these findings in a larger, more diverse patient population and over a longer follow-up period.

**Conflicts of interest.** The authors declare no conflict of interest.

**Compliance with Ethical Standards.** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

**Use of Artificial Intelligence.** The authors confirm that no artificial intelligence (AI) tools or large language models were used in the creation of the manuscript, drafting of the text, or generation of figures.

**Primary Data and Materials.** The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

**Funding Information.** None.

**Acknowledgments.** This study was supported by the Department of Cardiology, Faculty of Medicine, Hasanuddin University for their assistance in providing, assisting and obtaining the text which form the basis for this manuscript. DSL – Conceptualization, Methodology, Investigation, Writing – Original Draft preparation; AFM – Conceptualization, Methodology, Investigation, Resources, Validation, Writing- Original Draft preparation, Writing – Review & Editing, Supervision; YP – Conceptualization, Methodology, Investigation, Resources, Validation, Writing- Original Draft preparation, Writing – Review & Editing, Supervision; MA – Validation, Writing – Review & Editing, Supervision; ZD – Validation, Writing – Review & Editing, Supervision; MW – Validation, Writing – Review & Editing, Supervision; AAZ – Methodology, Formal Analysis. All authors read and approved the final version of the manuscript.

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## Порівняльний вплив 12 тижнів тренувань у центрі та вдома на рівні hs-CRP та IL-6 у пацієнтів із серцевою недостатністю. Зниження фракції викиду

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**Резюме**

**Вступ.** Серцева недостатність (СН) є глобальною проблемою охорони здоров'я, що характеризується значною захворюваністю та смертністю, часто пов'язаною з хронічним системним запаленням. Кардіологічна реабілітація на основі фізичних вправ є основою лікування СН, проте обмеження доступності часто обмежують участь у ній. Програми фізичних вправ для виконання вдома є потенційно життєздатною альтернативою. Це дослідження вивчає порівняльні ефекти тренувань у центрі та вдома на маркери запалення у пацієнтів із СН та зниженою фракцією викиду.

**Мета.** Оцінити вплив 12-тижневих фізичних вправ у фітнес-центрі та вдома на маркери запалення, зокрема високочутливий С-реактивний білок (hs-CRP) та інтерлейкін-6 (IL-6), у пацієнтів із серцевою недостатністю та зниженою фракцією викиду.

**Матеріали та методи.** Було застосовано квазіекспериментальний дизайн, в якому взяли участь 31 пацієнт з діагнозом серцева недостатність з фракцією викиду лівого шлуночка нижче 40 %. Учасники були розподілені на дві групи: фізичні вправи в центрі (n=15) та фізичні вправи вдома (n=16). Обидві групи пройшли 12-тижневу програму реабілітації, що складалася з сеансів легкої інтенсивності п'ять разів на тиждень. Були зібрані зразки крові до та після втручання для вимірювання рівнів hs-CRP та IL-6 у сироватці крові. Також були записані клінічні та демографічні дані. Статистичний аналіз було проведено за допомогою тестів Манна–Уїтні та Вілкоксона, з рівнем значущості $p<0{,}05$.

**Результати та обговорення.** Обидва види фізичних вправ призвели до значного зниження рівнів IL-6 та hs-CRP після 12 тижнів ($p<0{,}001$). Медіана IL-6 знизилася з 13,1 пг/мл до 4,8 пг/мл, а медіана hs-CRP знизилася з 4,3 мг/л до 2,5 мг/л у всіх учасників. Не було виявлено статистично значущих відмінностей між групою, що тренувалася в центрі, та групою, що тренувалася вдома, за ступенем зниження рівня обох біомаркерів (IL-6, $p = 0{,}906$; hs-CRP, $p = 0{,}200$).

**Висновки.** Дванадцятитижневе тренування вдома є таким же ефективним, як і тренування в центрі, для зменшення системного запалення, виміряного за допомогою IL-6 та hs-CRP, у пацієнтів із серцевою недостатністю зі зниженою фракцією викиду. Ці результати підтверджують доцільність використання реабілітації вдома як альтернативи програмам у центрі для лікування запалення у цій групі пацієнтів.

***Ключові слова:*** *кардіологічна реабілітація, маркери запалення, HFrEF, цитокіни, амбулаторна допомога*

Стаття надійшла в редакцію / Received: 27.10.2025
Після доопрацювання / Revised: 14.11.2025
Прийнято до друку / Accepted: 3.11.2025