

Digital Biofeedback–Based Nursing Program for Improving Physiological Regulation, Anxiety, Sleep Quality, and Self-Management among Patients with Heart Failure

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Abstract

Background: Heart failure is a complex chronic condition characterized by impaired cardiovascular function and persistent physiological stress, often accompanied by anxiety, poor sleep quality, and difficulties in maintaining effective self-management. Digital biofeedback may provide patients with real-time physiological information that supports relaxation, symptom awareness, behavioral regulation, and active participation in disease management. **Aim:** To evaluate the effect of a digital biofeedback–based nursing program on physiological regulation, anxiety, sleep quality, and self-management among patients with heart failure. **Subjects and Methods:** A quasi-experimental one-group pretest–posttest design was used. A purposive sample of 100 adult patients diagnosed with heart failure was recruited from the cardiac and medical outpatient clinics of Sohag University Hospitals. Data were collected using a structured patient assessment questionnaire, a physiological regulation assessment, the Generalized Anxiety Disorder Scale (GAD-7), the Pittsburgh Sleep Quality Index (PSQI), and a heart failure self-management assessment scale. The nursing program incorporated digital biofeedback-assisted breathing and relaxation exercises, physiological monitoring, symptom recognition, medication and dietary adherence, sleep-management strategies, and individualized self-management education. The intervention was implemented through structured sessions with digital biofeedback

practice and follow-up support. **Results:** Following implementation of the program, patients demonstrated significant improvement in physiological regulation, with greater ability to recognize and control physiological responses. Anxiety levels decreased significantly, while sleep quality improved. A significant improvement was also observed in patients' self-management behaviors, including medication adherence, symptom monitoring, dietary and fluid management, physical activity, and appropriate responses to worsening symptoms. Significant differences were observed between pre- and post-intervention measurements ($p < 0.001$). **Conclusion:** The Digital Biofeedback–Based Nursing Program was effective in improving physiological regulation and reducing anxiety while enhancing sleep quality and self-management among patients with heart failure. **Recommendations:** Digital biofeedback should be incorporated into nursing-led heart failure management programs as a supportive strategy for physiological regulation, psychological well-being, sleep improvement, and long-term self-management.

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Introduction

Heart failure (HF) is a complex clinical syndrome resulting from structural or functional impairment of cardiac function, leading to reduced cardiac output and/or elevated intracardiac pressures. It remains a major global health problem and is associated with substantial morbidity, mortality, repeated hospitalizations, impaired functional capacity, and reduced quality of life. Despite advances in pharmacological and non-pharmacological treatment, many patients continue to experience persistent symptoms and difficulties in maintaining optimal disease control, highlighting the need for comprehensive nursing interventions that extend beyond conventional medical management (McDonagh et al., 2021).

Physiological dysregulation is an important component of the heart failure experience. Patients may develop alterations in autonomic nervous system activity, cardiovascular responses, respiratory patterns, and stress-related physiological processes. Sympathetic overactivation and impaired autonomic balance can contribute to disease progression and symptom burden, while psychological stress may further aggravate physiological instability (Varzideh et al., 2026). Therefore, interventions that promote awareness and voluntary regulation of physiological responses may provide a valuable complementary approach within comprehensive heart failure nursing care (Ponikowski et al., 2016).

Anxiety is another frequent psychological burden among individuals with heart failure. Concerns about symptoms, disease progression,

hospitalization, physical limitations, and uncertainty regarding the future can contribute to persistent anxiety. Elevated anxiety may negatively influence symptom perception, treatment adherence, sleep, physical activity, and self-care behaviors, creating a cycle in which psychological distress and disease-management difficulties reinforce one another. Consequently, addressing psychological well-being should be considered an integral component of holistic heart failure nursing management (Costa et al., 2022).

Sleep disturbance is also common among patients with heart failure and may include difficulty initiating or maintaining sleep, fragmented sleep, excessive daytime sleepiness, and poor perceived sleep quality. Poor sleep may contribute to fatigue, impaired concentration, reduced physical functioning, psychological distress, and decreased ability to perform appropriate self-care. Furthermore, sleep disturbances may interact with cardiovascular and autonomic dysfunction, emphasizing the importance of incorporating sleep assessment and sleep-promoting strategies into nursing interventions for patients with heart failure (Zheng, 2021).

Self-management represents a cornerstone of effective heart failure care. It includes daily monitoring of symptoms and weight, adherence to prescribed medications, dietary and fluid management, appropriate physical activity, recognition of worsening symptoms, and timely communication with healthcare providers. However, maintaining these behaviors can be challenging because heart failure requires continuous decision-making and behavioral adaptation. Nurse-led interventions that provide individualized

education, skill development, monitoring, and ongoing reinforcement can strengthen patients' confidence and ability to manage their condition effectively (Jaarsma et al., 2021).

Digital health technologies have created new opportunities for delivering individualized and interactive nursing care. Biofeedback is a technology-assisted approach through which individuals receive real-time information about physiological processes, such as heart rate, respiratory rate, or other measurable responses, and learn techniques to modify these responses voluntarily (Hirten et al., 2024). When integrated with structured breathing, relaxation, and behavioral training, biofeedback may enhance patients' awareness of their physiological state and promote active participation in symptom and stress regulation (Li et al., 2025).

The integration of biofeedback technology with nursing care may therefore offer a promising strategy for addressing multiple interrelated dimensions of heart failure management. Rather than focusing exclusively on physiological parameters, a digital biofeedback–based nursing program can combine physiological regulation with anxiety reduction, sleep-management strategies, health education, symptom monitoring, and self-management training. This integrated approach is consistent with contemporary patient-centered heart failure care, which emphasizes multidisciplinary support, patient engagement, behavioral modification, and continuity of care (McDonagh et al., 2021).

The nurse plays a central role in implementing the Digital Biofeedback–Based Nursing Program by conducting comprehensive assessment of patients' demographic and clinical characteristics, heart failure symptoms, physiological parameters, anxiety, sleep quality, and self-management practices. The nurse introduces and demonstrates the digital biofeedback device/application, explains its purpose and safe use, and guides patients in interpreting real-time physiological information. Individualized breathing, relaxation, and physiological self-regulation exercises are practiced with biofeedback, while the nurse provides reassurance, psychological support, and reinforcement to reduce anxiety and improve patients' awareness and control of stress-related physiological responses. (Wathne et al., 2025).

The nurse also provides individualized education and coaching regarding sleep hygiene, medication adherence, dietary and fluid management, daily symptom and weight monitoring, appropriate physical activity, recognition of warning signs, and timely healthcare seeking. Patients are encouraged to integrate biofeedback-assisted breathing and relaxation into their daily routine, particularly during periods of stress or before sleep. Through regular follow-up, the nurse evaluates adherence to the program, monitors changes in physiological and behavioral responses, identifies barriers to self-management, reinforces positive behaviors, and modifies education according to patients' needs. Thus, the nurse functions as an educator, biofeedback facilitator, psychological supporter, physiological-monitoring guide, and self-management coach, while digital technology remains a supportive tool rather than a replacement for professional nursing judgment (Longhini et al., 2025).

Significance of the Study

Heart failure is a chronic condition that requires continuous self-management and is frequently associated with physiological dysregulation, anxiety, sleep disturbances, and difficulties in maintaining recommended health behaviors. These interrelated problems may negatively affect symptom control, functional capacity, quality of life, treatment adherence, and overall disease outcomes. Although conventional heart failure management emphasizes pharmacological treatment and patient education, there is a growing need for nursing interventions that actively engage patients in monitoring and regulating their physiological and psychological responses. Digital biofeedback provides an interactive approach that can help patients recognize physiological changes in real time and learn techniques to promote relaxation and self-regulation.

A Digital Biofeedback–Based Nursing Program may provide an innovative, patient-centered approach by integrating physiological monitoring, biofeedback-assisted breathing and relaxation, anxiety management, sleep-health education, and heart failure self-management training. The nurse has an important role in translating digital physiological information into understandable and practical self-care behaviors while providing individualized education, psychological support, and follow-up. Therefore, evaluating this integrated program

may contribute to strengthening the role of nurses in technology-supported chronic disease management and improving patients' active participation in long-term heart failure care.

Aim of the Study

The aim of the present study is to evaluate the effectiveness of a Digital Biofeedback–Based Nursing Program on physiological regulation, anxiety, sleep quality, and self-management among patients with heart failure.

Research Hypotheses

- Patients with heart failure who receive the Digital Biofeedback–Based Nursing Program will demonstrate significantly improved physiological regulation after the intervention compared with their pre-intervention levels.
- Patients with heart failure who receive the program will demonstrate a significant reduction in anxiety levels after the intervention compared with their pre-intervention levels.
- Patients with heart failure who receive the program will demonstrate significantly improved sleep quality after the intervention compared with their pre-intervention levels.
- Patients with heart failure who receive the program will demonstrate significantly improved self-management behaviors after the intervention compared with their pre-intervention levels.
- There will be a significant relationship between improvement in physiological regulation and improvement in anxiety, sleep quality, and self-management among patients with heart failure following implementation of the program.

Subjects and Methods

Research Design

A quasi-experimental one-group pretest–posttest design was used to evaluate the effectiveness of a Digital Biofeedback–Based Nursing Program on physiological regulation, anxiety, sleep quality, and self-management among patients with heart failure.

Research Setting

The study was conducted in the Cardiology and Medical Outpatient Clinics at Sohag

University Hospitals, Sohag Governorate, Egypt, where patients with heart failure receive regular assessment, treatment, education, and follow-up.

Subjects and Sample

A purposive sample of 100 adult patients diagnosed with heart failure was recruited according to the predetermined eligibility criteria. Patients were approached during their routine outpatient visits and enrolled after confirming their eligibility and willingness to participate.

Inclusion Criteria

Patients were included if they:

1. Were **18 years or older**.
2. Had a confirmed diagnosis of heart failure.
3. Were clinically stable and able to participate in the nursing program.
4. Were able to communicate verbally and understand the study instructions.
5. Had sufficient cognitive and physical ability to use the digital biofeedback device/application.
6. Agreed to participate in the study.

Exclusion Criteria

Patients were excluded if they had:

1. Severe cognitive impairment or inability to understand the intervention.
2. Severe psychiatric or neurological disorders interfering with participation.
3. Acute decompensated heart failure requiring emergency hospitalization at the time of enrollment.
4. Severe visual, auditory, or physical impairment preventing use of the digital biofeedback system.
5. Participation in another structured psychological or digital self-management program during the study period.

Sample Size Calculation

The sample size was calculated using **Cochran's formula** for estimating a population proportion:

$$n = \frac{Z^2 P(1-P)}{d^2}$$

Where:

- **n** = required sample size
- **Z** = standard normal deviation corresponding to a 95% confidence level = **1.96**
- **P** = expected proportion of the studied characteristic = **0.50**
- **d** = acceptable margin of error = **0.05**

Data Collection Tools

Tool I: Structured Heart Failure Patient Assessment Questionnaire

A structured heart failure patient assessment questionnaire was developed by the researchers after reviewing relevant literature and guidelines concerning heart failure management, clinical characteristics, symptom burden, treatment, and lifestyle behaviors. The tool was used to collect baseline information and consisted of three parts.

Part I assessed the patients' sociodemographic characteristics, including age, sex, marital status, residence, educational level, occupation, and living arrangements.

Part II covered clinical characteristics, including duration of heart failure, heart failure classification, comorbidities, previous hospitalization, previous cardiac procedures, and frequency of follow-up.

Part III assessed lifestyle and health-related characteristics, including smoking, dietary habits, fluid intake, physical activity, medication adherence, sleep pattern, symptom monitoring, and previous experience with digital health technologies. The content of this tool was guided by contemporary heart failure management recommendations emphasizing comprehensive clinical assessment, lifestyle modification, treatment adherence, symptom monitoring, and patient-centered follow-up (McDonagh et al., 2021).

Tool II: Physiological Regulation and Digital Biofeedback Assessment Tool

The Physiological Regulation and Digital Biofeedback Assessment Tool was developed by the researchers based on literature addressing physiological stress regulation, autonomic nervous system activity, heart rate variability, and biofeedback-assisted regulation. The tool was designed to assess patients' physiological responses and their ability to achieve improved physiological regulation during digital biofeedback training. **Part I** included assessment of measurable physiological parameters, such as heart rate, respiratory rate, and blood pressure, in addition to other physiological indicators available through the digital biofeedback system. **Part II** assessed physiological regulation performance, including the ability to perform paced breathing, maintain a regular breathing pattern, respond appropriately to biofeedback information, use relaxation techniques, and demonstrate improved control of physiological responses. Biofeedback was used as a supportive technique through which patients received real-time information about physiological changes and learned to modify these responses through breathing and relaxation strategies (Lehrer & Gevirtz, 2014).

Scoring: Physiological parameters were recorded according to their actual measured values. For performance items, **1 point** was given for each correctly performed behavior and **0 points** for an incorrectly performed or unperformed behavior. Higher scores indicated better physiological regulation performance.

The physiological regulation performance level was classified as:

- **Poor:** <60%
- **Moderate:** 60–<75%
- **Good:** ≥75%

Tool III: Generalized Anxiety Disorder-7 (GAD-7)

The **Generalized Anxiety Disorder-7 (GAD-7)** was used to assess the severity of anxiety symptoms among patients with heart failure. The scale consists of seven items addressing the frequency of anxiety-related symptoms experienced during the previous two weeks. Each item is rated on a four-point scale ranging from **0 = not at all** to **3 = nearly every day**. The total score ranges from **0 to 21**, with higher scores indicating greater anxiety severity. The GAD-7 is a brief, validated instrument widely used for assessing

generalized anxiety symptoms in clinical populations (Spitzer et al., 2006).

Scoring: Each item was scored as follows: **0 = Not at all, 1 = Several days, 2 = More than half the days, and 3 = Nearly every day.** A higher total score indicated a greater severity of anxiety symptoms. The total score was obtained by summing the seven items and was interpreted as:

- **0–4:** Minimal anxiety
- **5–9:** Mild anxiety
- **10–14:** Moderate anxiety
- **15–21:** Severe anxiety

Tool IV: Pittsburgh Sleep Quality Index (PSQI)

The **Pittsburgh Sleep Quality Index (PSQI)** was used to assess subjective sleep quality and sleep disturbances among patients with heart failure during the previous month. The PSQI consists of seven sleep components: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction. Each component receives a score from 0 to 3, producing a global score ranging from 0 to 21. Higher scores indicate poorer sleep quality. The PSQI is a widely established instrument for evaluating subjective sleep quality and differentiating good and poor sleepers (Buysse et al., 1989).

Scoring: Each of the seven components was scored from **0 to 3**, and the component scores were summed to obtain the global PSQI score ranging from **0–21**. Thus, a decrease in the global PSQI score after the intervention indicated improvement in sleep quality. The total score was interpreted as:

- **0–5:** Good sleep quality
- **>5:** Poor sleep quality

Tool V: Heart Failure Self-Management Assessment Scale

The Heart Failure Self-Management Assessment Scale was developed by the researchers based on contemporary concepts of heart failure self-care and recommendations emphasizing patients' participation in self-care maintenance, symptom perception, and self-care management. The scale assessed patients' ability to perform recommended daily behaviors necessary for maintaining clinical

stability and responding appropriately to changes in their condition (Riegel et al., 2017). It consisted of five domains: medication management, including adherence to prescribed medications and schedules; dietary and fluid management, including sodium and fluid restriction according to the prescribed plan; symptom and weight monitoring, including monitoring of body weight, dyspnea, edema, and fatigue; physical activity and lifestyle management, including appropriate activity and lifestyle modification; and symptom management and healthcare-seeking behavior, including recognition of worsening symptoms and timely communication with healthcare providers.

Scoring: Each item was scored using a three-point response scale: 2 = regularly/always performed, 1 = sometimes performed, and 0 = never performed. A higher percentage score indicated better heart failure self-management. The overall self-management level was classified as:

- **Poor:** <60%
- **Moderate:** 60–<75%
- **Good:** ≥75%

Validity

The content validity of the study tools was assessed by a panel of **five experts** from the fields of Medical-Surgical Nursing, Psychiatric Nursing, Community Health Nursing, and Cardiology/Medicine. The experts reviewed the tools for relevance, clarity, comprehensiveness, appropriateness, and applicability to patients with heart failure. Their recommendations were considered, and necessary modifications were made before the final data collection.

Reliability

The reliability of the study tools was tested using Cronbach's alpha coefficient to assess their internal consistency. The tools demonstrated acceptable reliability, with Cronbach's alpha coefficients indicating satisfactory consistency among the included items (0.88). The same procedures were applied before the implementation of the main intervention to ensure the stability and consistency of the measurements.

Pilot Study

A pilot study was conducted on 10% of the total study sample (10 patients) before starting the main study. The pilot study aimed to assess the clarity, sequence, and applicability of the study tools, estimate the time required for completing the assessment, and evaluate the feasibility of the digital biofeedback procedures and nursing intervention. Necessary modifications were made based on the pilot findings. Patients who participated in the pilot study were excluded from the main study sample to avoid potential contamination or duplication of data.

Ethical Considerations

The study was conducted after obtaining approval from the appropriate ethical and scientific authorities of Sohag University (168/2023). Written informed consent was obtained from each participant after explaining the purpose, procedures, potential benefits, and voluntary nature of participation. Patients were informed that they had the right to withdraw from the study at any time without affecting their usual medical or nursing care. Confidentiality and anonymity were maintained throughout the study, and collected data were used solely for research purposes.

Phases of the Intervention

The Digital Biofeedback–Based Nursing Program was implemented through four sequential phases: assessment and preparation, implementation, consolidation, and follow-up. The program was delivered individually to patients with heart failure to allow personalization according to their physiological, psychological, sleep, and self-management needs.

Phase I: Assessment and Preparation Phase

During this phase, baseline data were collected before starting the intervention. The nurse assessed patients' sociodemographic and clinical characteristics, physiological regulation, anxiety level, sleep quality, and self-management practices. The nurse also introduced the concept of digital biofeedback, explained the purpose and benefits of the program, demonstrated the digital device/application, and assessed the patient's ability to use it safely.

Session 1: Initial Assessment and Orientation

- Duration: **45–60 minutes**
- Assessment of baseline physiological and psychosocial status.
- Explanation of heart failure and the relationship between physiological stress, anxiety, sleep, and self-management.
- Introduction to digital biofeedback and demonstration of the device/application.
- Training on recording symptoms and physiological responses.

Phase II: Implementation Phase

This phase focused on practical training and behavioral modification. Patients received **six structured sessions**, delivered over approximately **4 weeks**, with each session lasting **45–60 minutes**.

Session 2: Physiological Regulation and Biofeedback Training

- Duration: **45–60 minutes**
- Explanation of physiological responses to stress.
- Training in diaphragmatic and paced breathing.
- Guided biofeedback-assisted breathing exercises.
- Observation of real-time physiological responses.
- Repeated practice until the patient could perform the technique correctly.

Session 3: Anxiety Management and Relaxation

- Duration: **45–60 minutes**
- Identification of common heart failure-related anxiety triggers.
- Biofeedback-assisted relaxation training.
- Breathing control and muscle-relaxation exercises.
- Teaching strategies for managing anxiety during symptom exacerbation or stressful situations.
- Encouragement of daily relaxation practice.

Session 4: Sleep-Quality Improvement

- Duration: **45–60 minutes**
- Assessment of sleep-related problems.
- Education regarding sleep hygiene and regular sleep routines.
- Reduction of behaviors that interfere with sleep.

- Practice of slow breathing and relaxation using digital biofeedback before bedtime.
- Development of an individualized bedtime routine.

Session 5: Heart Failure Self-Management

- Duration: **45–60 minutes**
- Medication adherence and safe medication practices.
- Low-sodium dietary practices and appropriate fluid management according to the prescribed plan.
- Daily weight and symptom monitoring.
- Appropriate physical activity according to the patient's clinical condition.
- Recognition of warning signs, including increasing dyspnea, edema, rapid weight gain, and unusual fatigue.
- Guidance regarding when to contact the healthcare provider.

Session 6: Integration of Biofeedback into Daily Self-Care

- Duration: **45–60 minutes**
- Integration of biofeedback-assisted breathing and relaxation into daily routines.
- Training patients to use biofeedback during periods of anxiety or physiological stress.
- Reinforcement of sleep and self-management behaviors.
- Individualized problem-solving regarding barriers to adherence.
- Practical demonstration and return demonstration by each patient.

Session 7: Consolidation and Individualized Practice

- Duration: **45–60 minutes**
- Review of all previously taught skills.
- Reassessment of the patient's ability to perform biofeedback exercises independently.
- Correction of incorrect techniques.
- Reinforcement of effective self-management behaviors.
- Development of an individualized home practice plan.

Phase III: Consolidation Phase

At the end of the structured sessions, the nurse reinforced the acquired knowledge and skills and encouraged patients to continue daily

biofeedback-assisted breathing and relaxation exercises. Patients were provided with simple written instructions regarding physiological regulation, anxiety management, sleep hygiene, medication adherence, symptom monitoring, dietary and fluid management, and warning signs requiring medical consultation. The nurse encouraged patients to integrate the program into their normal daily routines.

Phase IV: Follow-Up Phase

Follow-up was conducted **4 weeks after completion of the intervention** to evaluate the sustainability of the program's effects. The nurse reassessed physiological regulation, anxiety, sleep quality, and self-management practices using the same study tools. Patients were encouraged to maintain regular biofeedback practice and heart failure self-management behaviors, and individualized reinforcement was provided when needed.

Statistical Analysis

The collected data were coded, tabulated, and statistically analyzed using the Statistical Package for the Social Sciences (SPSS), version 26. Descriptive statistics were used to summarize the study variables. Frequencies and percentages were calculated for categorical variables, while means and standard deviations (Mean $\pm$ SD) were used for quantitative variables. The median and range were also presented when appropriate. For comparison of the studied patients' outcomes before and after implementation of the Digital Biofeedback–Based Nursing Program, the paired-samples t-test was used for normally distributed quantitative variables, while the Wilcoxon signed-rank test was used for non-normally distributed quantitative variables. For categorical variables measured before and after the intervention, the McNemar test was used for dichotomous variables, whereas the McNemar–Bowker test was applied to categorical variables with more than two related categories. The Pearson correlation coefficient (r) was used to examine the relationships between normally distributed quantitative variables, while Spearman's rank correlation coefficient (ρ) was used for non-normally distributed variables. Correlations were used particularly to examine the relationships between physiological regulation, anxiety, sleep quality, and self-management outcomes after the intervention. The statistical significance level was set at $p < 0.05$, while $p < 0.001$ was considered highly statistically

significant. A p -value ≥ 0.05 was considered statistically non-significant. Normality of quantitative data was assessed before selecting

Results:

Table (1): Distribution of the Studied Patients According to Their Sociodemographic Characteristics (n=100)

Sociodemographic characteristics	No.	%
Age (years)		
18–<40	18	18.0
40–<50	27	27.0
50–<60	31	31.0
≥ 60	24	24.0
Mean $\pm$ SD	53.7 $\pm$ 11.2	
Sex		
Male	62	62.0
Female	38	38.0
Marital status		
Married	78	78.0

Table (1) shows that 31.0% of the studied patients were aged 50–<60 years, with a mean age of 53.7 ± 11.2 years. Regarding sex, males constituted the majority of the studied patients (62.0%), whereas females represented 38.0%. Concerning marital status, the majority were married (78.0%). More than three-fifths of the

Table (2): Distribution of the Studied Patients According to Their Clinical Characteristics (n=100)

Clinical characteristics	No.	%
Duration of heart failure		
<2 years	24	24.0
2–<5 years	43	43.0
≥ 5 years	33	33.0
NYHA functional class		
Class II	42	42.0
Class III	48	48.0
Class IV	10	10.0
Associated comorbidities		
Hypertension	67	67.0

Table (2) reveals that 43.0% of the studied patients had heart failure for 2–<5 years, while 33.0% had the disease for five years or more. Regarding functional status, nearly half of the patients (48.0%) were classified as NYHA class III, followed by class II (42.0%). Hypertension was the most frequent

the appropriate parametric or non-parametric statistical test.

Sociodemographic characteristics	No.	%
Single	8	8.0
Widowed/Divorced	14	14.0
Residence		
Rural	61	61.0
Urban	39	39.0
Educational level		
Illiterate	22	22.0
Basic education	28	28.0
Secondary education	31	31.0
University education	19	19.0
Occupation		
Employed	29	29.0
Not employed	71	71.0
Living arrangement		
With spouse/family	88	88.0
Alone	12	12.0

patients were from rural areas (61.0%). Regarding educational level, 31.0% had secondary education, while 22.0% were illiterate. Most patients were not employed (71.0%), and the vast majority lived with their spouse or family (88.0%).

Clinical characteristics	No.	%
Diabetes mellitus	49	49.0
Ischemic heart disease	54	54.0
Renal disease	18	18.0
None	11	11.0
Previous HF-related hospitalization		
Yes	64	64.0
No	36	36.0
Regular cardiac follow-up		
Yes	58	58.0
No	42	42.0

comorbidity (67.0%), followed by ischemic heart disease (54.0%) and diabetes mellitus (49.0%). Nearly two-thirds of the studied patients (64.0%) had experienced previous HF-related hospitalization. Regular cardiac follow-up was reported by 58.0% of the patients.

Table (3): Distribution of the Studied Patients According to Their Lifestyle and Health-Related Characteristics Before the Intervention (n=100)

Characteristics	No.	%
Current smoking	31	31.0
Adherence to low-salt diet	38	38.0
Adherence to fluid restriction	41	41.0
Regular physical activity	29	29.0

Table (3) demonstrates that the studied patients had several unfavorable health-related behaviors before implementation of the program. Only 38.0% reported adherence to a low-salt diet, while 41.0% adhered to fluid restriction. Regular physical activity was reported by only 29.0% of the patients. Less

Table (4): Comparison of Physiological Parameters among the Studied Patients Before and After the Digital Biofeedback-Based Nursing Program (n=100)

Physiological parameters	Pre-intervention Mean $\pm$ SD	Post-intervention Mean $\pm$ SD	Paired t-test	p-value
Heart rate (beats/min)	84.7 $\pm$ 8.6	76.9 $\pm$ 7.2	8.41	<0.001 **
Respiratory rate (breaths/min)	21.4 $\pm$ 3.1	18.3 $\pm$ 2.4	8.02	<0.001 **

Table (4) indicates statistically significant improvement in all assessed physiological parameters following implementation of the digital biofeedback-based nursing program. Mean heart rate decreased from 84.7 $\pm$ 8.6 to 76.9 $\pm$ 7.2 beats/min, while respiratory rate

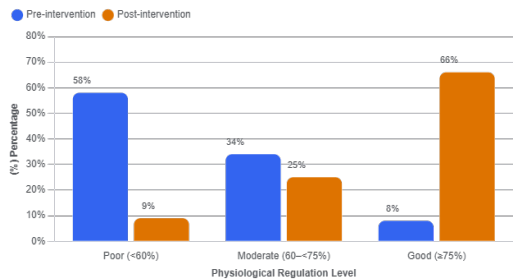


Figure (1): shows a marked improvement in physiological regulation following the intervention. Before the program, 58.0% of patients had poor physiological regulation and only 8.0% had good regulation. After the intervention, the proportion with poor

Characteristics	No.	%
Regular medication adherence	47	47.0
Regular daily weight monitoring	21	21.0
Regular symptom monitoring	34	34.0
Previous experience with digital health	26	26.0
Sleep problems	73	73.0

than half (47.0%) reported regular medication adherence. Daily weight and symptom monitoring were relatively low (21.0% and 34.0%, respectively). Only 26.0% had previous experience with digital health, whereas sleep problems were reported by nearly three-quarters of the patients (73.0%).

Physiological parameters	Pre-intervention Mean $\pm$ SD	Post-intervention Mean $\pm$ SD	Paired t-test	p-value
Systolic BP (mmHg)	138.6 $\pm$ 16.4	128.9 $\pm$ 13.2	6.18	<0.001 **
Diastolic BP (mmHg)	84.7 $\pm$ 9.8	79.1 $\pm$ 8.1	5.34	<0.001 **

decreased from 21.4 $\pm$ 3.1 to 18.3 $\pm$ 2.4 breaths/min. Mean systolic and diastolic blood pressure also decreased significantly after the intervention. All observed differences were highly statistically significant ($p<0.001$).

Figure (1): Distribution of the Studied Patients According to Their Physiological Regulation Level Before and After the Intervention (n=100)

regulation decreased markedly to 9.0%, whereas those with good regulation increased to 66.0%. The observed change was highly statistically significant (McNemar-Bowker=46.72, $p<0.001$).

Table (5): Comparison of Digital Biofeedback-Related Performance among the Studied Patients Before and After the Intervention (n=100)

Biofeedback performance item	Pre-intervention No. (%)	Post-intervention No. (%)	McNemar test	p-value
Performs paced breathing correctly	35 (35.0)	87 (87.0)	43.21	<0.001**
Maintains regular breathing pattern	41 (41.0)	90 (90.0)	45.00	<0.001**
Follows	29 (29.0)	84 (84.0)	44.10	<0.001**

Table (5) demonstrates substantial improvement in all digital biofeedback-related performance items after the nursing program. Correct paced breathing increased from 35.0% before the intervention to 87.0% afterward. Similarly, correct interpretation of digital

Table (6): Comparison of Total Anxiety Scores among the Studied Patients Before and After the Intervention (n=100)

Table (6) reveals a highly significant reduction in the mean anxiety score following implementation of the nursing program. The mean GAD-7 score decreased from 12.8 ± 4.3

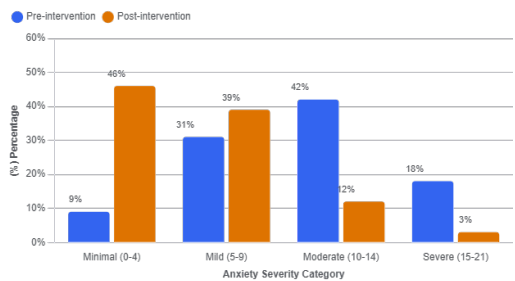


Figure (2): Distribution of the Studied

Figure (2) shows a clear shift toward lower anxiety severity after the intervention. Before the program, 60.0% of patients had moderate or severe anxiety, compared with only 15.0%

Table (7): Comparison of PSQI Global and Component Scores Before and After the Intervention (n=100)

Biofeedback performance item	Pre-intervention No. (%)	Post-intervention No. (%)	McNemar test	p-value
digital feedback signals correctly				1**
Performs relaxation technique correctly	32 (32.0)	88 (88.0)	45.31	<0.001**
Demonstrates physiological control	27 (27.0)	82 (82.0)	43.82	<0.001**

feedback increased from 29.0% to 84.0%, while the ability to perform relaxation techniques increased from 32.0% to 88.0%. All improvements were highly statistically significant ($p < 0.001$).

Variable	Pre-intervention Mean $\pm$ SD	Post-intervention Mean $\pm$ SD	Paired t-test	p-value
GAD-7 total score	12.8 ± 4.3	6.4 ± 3.1	14.26	<0.001**

before the intervention to 6.4 ± 3.1 after the intervention, with a highly statistically significant difference ($t = 14.26$, $p < 0.001$).

Patients According to Anxiety Severity Before and After the Intervention (n=100)

after the intervention. Conversely, minimal anxiety increased from 9.0% before the program to 46.0% afterward.

PSQI variables	Pre-intervention Mean $\pm$ SD	Post-intervention Mean $\pm$ SD	Paired t-test	p-value
Subjective sleep	1.8 ± 0.7	1.0 ± 0.6	8.73	<0.001**

PSQI variables	Pre-intervention Mean $\pm$ SD	Post-intervention Mean $\pm$ SD	Paired t-test	p-value
quality				
Sleep latency	1.7 $\pm$ 0.8	1.0 $\pm$ 0.6	7.22	<0.001 **
Sleep duration	1.6 $\pm$ 0.8	0.9 $\pm$ 0.6	7.45	<0.001 **
Habitual sleep efficiency	1.5 $\pm$ 0.8	0.8 $\pm$ 0.6	7.31	<0.001 **
Sleep disturbances	1.7 $\pm$ 0.7	1.0 $\pm$ 0.6	8.12	<0.001 **
Sleep	0.9 $\pm$ 0.9	0.5 $\pm$ 0.7	4.11	<0.001

Table (7) indicates significant improvement across all seven PSQI components after implementation of the program. The global

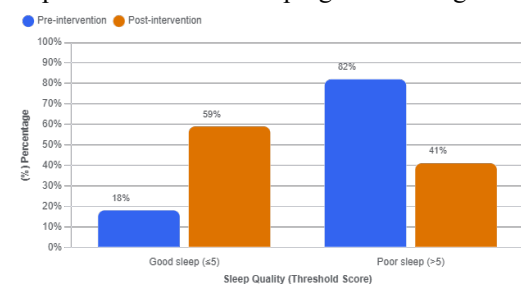


Figure (3): demonstrates a marked improvement in overall sleep quality after the intervention. The percentage of patients with

Table (8): Comparison of Heart Failure Self-Management Domains Before and After the Intervention (n=100)

Self-management domain	Pre-intervention Mean $\pm$ SD	Post-intervention Mean $\pm$ SD	Paired t-test	p-value
Medication management	61.4 $\pm$ 13.2	82.7 $\pm$ 10.6	13.21	<0.001 **
Dietary/fluid management	57.8 $\pm$ 14.1	79.8 $\pm$ 11.7	12.64	<0.001 **
Symptom and weight monitoring	49.6 $\pm$ 16.3	77.4 $\pm$ 12.5	14.87	<0.001 **
Physical activity/lifestyle	53.2 $\pm$ 15.4	75.9 $\pm$ 13.1	12.18	<0.001 **

Table (8) shows statistically significant improvement in all five domains of heart failure self-management following the intervention. The total self-management score

PSQI variables	Pre-intervention Mean $\pm$ SD	Post-intervention Mean $\pm$ SD	Paired t-test	p-value
medication use				**
Daytime dysfunction	1.6 $\pm$ 0.8	0.9 $\pm$ 0.6	7.84	<0.001 **
Global PSQI score	10.8 $\pm$ 3.2	6.1 $\pm$ 2.5	11.73	<0.001

PSQI score decreased from 10.8 $\pm$ 3.2 before the intervention to 6.1 $\pm$ 2.5 afterward.

Figure (3): Distribution of the Studied Patients According to Overall Sleep Quality Before and After the Intervention (n=100)

good sleep increased from 18.0% before the program to 59.0% afterward, while poor sleep decreased from 82.0% to 41.0%.

Self-management domain	Pre-intervention Mean $\pm$ SD	Post-intervention Mean $\pm$ SD	Paired t-test	p-value
Symptom management/healthcare-seeking	55.7 $\pm$ 14.8	80.6 $\pm$ 11.8	13.74	<0.001 **
Total self-management score	55.5 $\pm$ 11.9	79.3 $\pm$ 9.8	16.02	<0.001

increased from 55.5 $\pm$ 11.9 before the program to 79.3 $\pm$ 9.8 after the program. The greatest improvement was observed in symptom and weight monitoring, followed by symptom

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management and healthcare-seeking. All differences were highly statistically significant

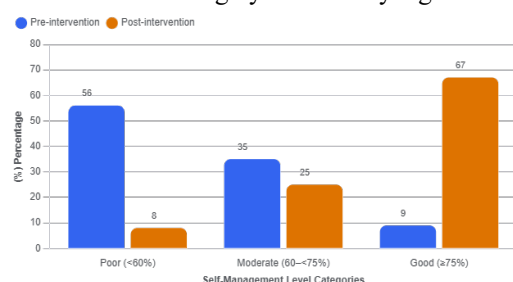


Figure (4) demonstrates a pronounced improvement in the overall self-management level after implementation of the digital biofeedback–based nursing program. Before the intervention, more than half of the patients

Table (9): Correlation between Physiological Regulation and Study Outcomes after the Intervention (n=100)

Table (9) demonstrates statistically significant relationships between physiological regulation and all major study outcomes after the intervention. Physiological regulation was negatively correlated with anxiety ($r=-0.52$, $p<0.05$), $p<0.05$, $p<0.001$.

Discussion:

Heart failure is a complex chronic condition that requires continuous physiological monitoring, symptom recognition, psychological support, and effective self-management. The present study evaluated a Digital Biofeedback–Based Nursing Program integrating physiological feedback, breathing and relaxation techniques, sleep-health education, and self-management support. The overall findings demonstrated significant improvements in physiological regulation, anxiety, sleep quality, and self-management after implementation of the program. These findings are generally consistent with recent evidence indicating that structured nursing, digital, telehealth, and technology-supported interventions can improve several dimensions of heart failure care, although the magnitude of benefit may vary according to intervention components, duration, follow-up, and patient engagement (Geng et al., 2025).

The present study showed that the largest proportion of patients were aged 50–<60 years, with a mean age of 53.7 ± 11.2 years, and males represented the majority of the sample.

($p<0.001$).

Figure (4): Distribution of the Studied Patients According to Their Overall Self-Management Level Before and After the Intervention (n=100)

(56.0%) had poor self-management, compared with only 8.0% after the intervention. The proportion achieving good self-management increased substantially from 9.0% to 67.0%.

Variables	Anxiety score	PSQI score	Self-management score
Physiological regulation score	$r = -0.52$, $p<0.001$	$r = -0.47$, $p<0.001$	$r = 0.58$, $p<0.001$

$p<0.001$) and PSQI score ($r=-0.47$, $p<0.001$). In contrast, a positive significant correlation was found between physiological regulation and self-management ($r=0.58$, $p<0.001$).

Most participants were married, lived in rural areas, and lived with their families. This pattern is generally consistent with Fahmi et al. (2026) recent heart failure intervention studies in which participants were predominantly middle-aged to older adults and commonly included a higher proportion of men and patients with NYHA class II–III disease, for example, reported that participants in nurse-led technology-based heart failure interventions were generally older adults, predominantly male, and mainly classified as NYHA II–III. The similarity may reflect the demographic and clinical profile of patients commonly receiving outpatient heart failure management.

Regarding clinical characteristics, nearly half of the studied patients were classified as NYHA class III, while hypertension, ischemic heart disease, and diabetes mellitus were the most frequently reported comorbidities. Furthermore, almost two-thirds had experienced previous hospitalization related to heart failure. These findings are compatible with the clinical complexity of heart failure populations described in recent intervention studies by Alexescu et al. (2026) reported that most participants in nurse-led technology-

based interventions were classified as NYHA II–III, supporting the relevance of technology-supported nursing care among patients with symptomatic but clinically manageable heart failure. Similarly, recent evidence emphasizes the importance of continuous monitoring and self-management support for patients at increased risk of deterioration and hospitalization.

The findings revealed several unfavorable self-care behaviors before implementation of the program. These findings are consistent with **Longhini et al. (2025)** recent literature emphasizing that heart failure self-care is multidimensional and often difficult to maintain in daily life and concluded that nursing interventions targeting patients at home can improve selected dimensions of heart failure self-care, particularly when interventions include education, monitoring, telephone or digital support, and follow-up. Therefore, the unfavorable baseline behaviors in the present study support the need for an integrated nursing intervention rather than education alone.

The present study demonstrated significant reductions in heart rate, respiratory rate, systolic blood pressure, and diastolic blood pressure following implementation of the Digital Biofeedback–Based Nursing Program. Blood pressure also showed significant improvement. These findings are consistent with **Geng et al.,(2025)** the physiological rationale of biofeedback-based interventions, in which real-time physiological information combined with controlled breathing and relaxation may facilitate improved autonomic regulation. The findings are also compatible with recent evidence showing that technology-supported monitoring and nursing interventions can positively influence clinical and self-care outcomes in heart failure.

A marked improvement was observed in the overall physiological regulation level, as the proportion of patients with poor regulation decreased after the intervention, whereas the proportion classified as having good regulation increased. The highly significant McNemar–Bowker test indicates that the improvement was not attributable to random variation. This finding agrees with **Rampengan et al., (2025)**, the underlying concept of biofeedback-assisted nursing care, where patients receive immediate information about physiological responses and are trained to modify breathing and relaxation behaviors. It is also consistent with the broader evidence that technology-supported

interventions may strengthen patients' ability to monitor and respond to physiological changes. However, direct comparisons should be made cautiously because recent heart failure technology studies have used different technologies and outcome measures.

The study demonstrated significant improvement in all biofeedback performance components, including paced breathing, regular breathing, following feedback signals, relaxation, and physiological control. The proportion correctly performing paced breathing increased. These findings supported by **de Souto Barbosa et al.,(2023)** about the effectiveness of structured nurse-guided training in helping patients use digital feedback as a practical self-regulation tool. The findings are broadly consistent with **Chelidoni et al., (2020)** recent evidence showing that nurse-led technology-based interventions improve patient participation in self-care and self-management. However, the present study differs from many previous interventions because biofeedback was directly incorporated into the nursing sessions rather than being used only for remote education or monitoring.

The present study showed a significant reduction in anxiety, with the mean GAD-7 score decreasing after the intervention. These findings suggest that integrating breathing regulation, relaxation, physiological feedback, education, and nurse support may contribute to psychological improvement. However, the findings differ somewhat from the recent meta-analysis by **Cen et al. (2026)**, which reported that nurse-led telecoaching did not produce a statistically significant overall reduction in anxiety. This difference may be explained by the nature of the present intervention, which directly incorporated relaxation and physiological regulation through biofeedback, whereas telecoaching studies varied substantially in content and intensity.

A significant improvement in sleep quality was observed following the intervention. Improvements were also observed across all seven PSQI components. These findings can be interpreted in relation to the combined effect of relaxation training, anxiety reduction, physiological regulation, and sleep-hygiene education. The findings are consistent with **Oberfrank et al., (2026)**, the broader evidence supporting multimodal nursing interventions in heart failure, particularly interventions that combine educational and psychological components. However, recent technology-

based reviews indicate that effects across psychological and quality-of-life outcomes are not always consistent, suggesting that the sleep improvement observed in the present study may be related specifically to its integrated biofeedback and nursing components rather than technology alone.

The strongest improvement was observed in heart failure self-management. Significant improvements were also observed in medication management, dietary and fluid management, symptom and weight monitoring, physical activity, and symptom management/healthcare-seeking. These findings strongly agree with **Longhini et al. (2025)**, who found that nursing interventions incorporating home care, transitional care, remote support, and digital interventions can improve selected dimensions of heart failure self-care. They are also strongly supported by **Fahmi et al. (2026)**, whose meta-analysis demonstrated significant improvements in self-care maintenance, self-management, and self-confidence following nurse-led technology-based interventions.

The categorical analysis further confirmed the effectiveness of the intervention. This finding is consistent with the umbrella review by **Oliveira et al., (2025)** which identified educational, psychological, and telehealth interventions as among the most effective approaches for improving heart failure self-care. The present findings also support the concept that technology is most beneficial when embedded within structured nursing education and follow-up rather than delivered as an isolated digital tool.

After implementation of the program, physiological regulation was negatively correlated with anxiety and PSQI score, while a positive correlation was observed with self-management. These relationships suggest that better physiological regulation was associated with lower anxiety and better sleep, while also being associated with stronger self-management behaviors. This pattern is conceptually consistent with **Alwhaibi & Al Aloola, (2023)**, recent evidence emphasizing the multifactorial nature of heart failure self-care, in which physiological monitoring, psychological support, education, and behavioral engagement interact rather than functioning as isolated outcomes. Nevertheless, these correlations should not be interpreted as evidence of causation.

Overall, the present study demonstrated significant improvement in all major outcomes: physiological regulation increased, anxiety decreased, PSQI decreased, and self-management increased. These findings are supported by the recent umbrella review by **Oberfrank et al. (2026)**, which concluded that different intervention categories significantly improve heart failure self-care, particularly when educational, psychological, and telehealth components are combined. They are also supported by **Fahmi et al. (2026)**, who demonstrated significant improvements in self-care maintenance, self-management, and self-confidence with nurse-led technology-based interventions. Nevertheless, the present findings should be interpreted within the context of a one-group pretest–posttest design, and future controlled studies are needed to establish the independent effect of digital biofeedback beyond routine nursing care.

Conclusion

Based on the findings of the present study, the findings of the present study demonstrated that the Digital Biofeedback–Based Nursing Program was effective in improving physiological regulation, reducing anxiety, enhancing sleep quality, and strengthening self-management among patients with heart failure. Significant improvements were observed in physiological parameters and biofeedback performance, with a marked shift toward better physiological regulation. Anxiety and sleep disturbances were significantly reduced, while all domains of heart failure self-management showed significant improvement. Furthermore, better physiological regulation was significantly associated with lower anxiety and better sleep quality, as well as higher self-management. These findings support the integration of digital biofeedback within structured nurse-led heart failure care as a supportive approach to promote physiological, psychological, and behavioral outcomes.

Recommendations

Based on the findings of the present study, the following recommendations are suggested:

- Integrating digital biofeedback into nurse-led heart failure management programs to support physiological regulation and patient self-management.
- Providing structured nursing education addressing medication adherence, dietary

and fluid management, symptom and weight monitoring, physical activity, sleep hygiene, and early recognition of warning signs.

- Using digital biofeedback-assisted breathing and relaxation techniques as supportive nursing strategies for patients experiencing anxiety and physiological stress.
- Establish regular digital follow-up and monitoring to reinforce self-management behaviors and identify early deterioration.
- Training cardiac and medical-surgical nurses in the appropriate use of digital biofeedback technologies, patient education, and interpretation of physiological feedback.
- Encourage individualized nursing plans according to patients' clinical status, technological abilities, psychological needs, and self-management barriers.
- Conducting future randomized controlled studies with larger samples and longer follow-up periods to confirm the effectiveness and sustainability of digital biofeedback–based nursing interventions.
- Investigating the cost-effectiveness and feasibility of integrating digital biofeedback into routine heart failure services, particularly in outpatient and community-based settings.

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