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ORIGINAL ARTICLE

Virtual Reality and Physical Activity in Patients with Heart Failure: Technology Validation and User Satisfaction – Pilot Study

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Abstract

Background: Digital health uses innovative information technology for healthcare needs. Virtual reality (VR) is increasingly adopted in healthcare, including cardiovascular rehabilitation (CVR), to improve performance and adherence. However, digital interventions must consider users' perspectives to prevent VR from becoming a barrier.

Objective: This study aimed to assess the usability and enjoyment of physical activity associated with VR among inpatients with heart failure (HF).

Method: A prospective pilot study was conducted with ten patients diagnosed with HF. Participants completed an exercise program on a cycle ergometer with immersive VR for lower limb training. Anxiety and depression symptoms, physical activity enjoyment, and system usability were evaluated. Statistical analysis included descriptive and inferential analyses with a 5% significance level ($p<0.05$). Pearson's test was used for correlation analysis.

Results: The population's tendency to experience anxiety and depression was evaluated, and the sample favorably assessed the system's usability, with a mean score of 68.2 (standard deviation ±17.8); exercise enjoyment scored 79.6 (±7.7). No significant correlations were found between anxiety and depression profiles and usability or exercise enjoyment, suggesting further study phases.

Conclusions: VR can complement rehabilitation programs for HF patients, potentially improving performance and adherence. Additional research is required to evaluate the effectiveness of VR-associated physical activity on clinical outcomes in HF patients.

Keywords: Virtual reality; digital health; heart failure; rehabilitation.

Introduction

Digital health is the "field of knowledge and practice related to the development and use of digital technologies to improve health".[1] It can be considered a cultural transformation of traditional healthcare, as digital technologies facilitate patients' participation in the care process.[2] This innovative approach adopts technologies such as artificial intelligence, wearable technology, and virtual reality (VR) to improve healthcare.

VR is a computer-generated simulated interactive three-dimensional experience that allows users to engage in real or imaginary environments.[3] It emerges as a promising auxiliary tool to promote treatment adherence and patient satisfaction and also improve attendance rates in rehabilitation programs.[4]

Noncommunicable diseases are the leading cause of death and disability worldwide.[5] Among them, cardiovascular diseases are the primary cause of mortality, with heart failure (HF) being the final common pathway of most diseases affecting the

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Central Illustration: Virtual Reality and Physical Activity in Patients with Heart Failure: Technology Validation and User Satisfaction – Pilot Study

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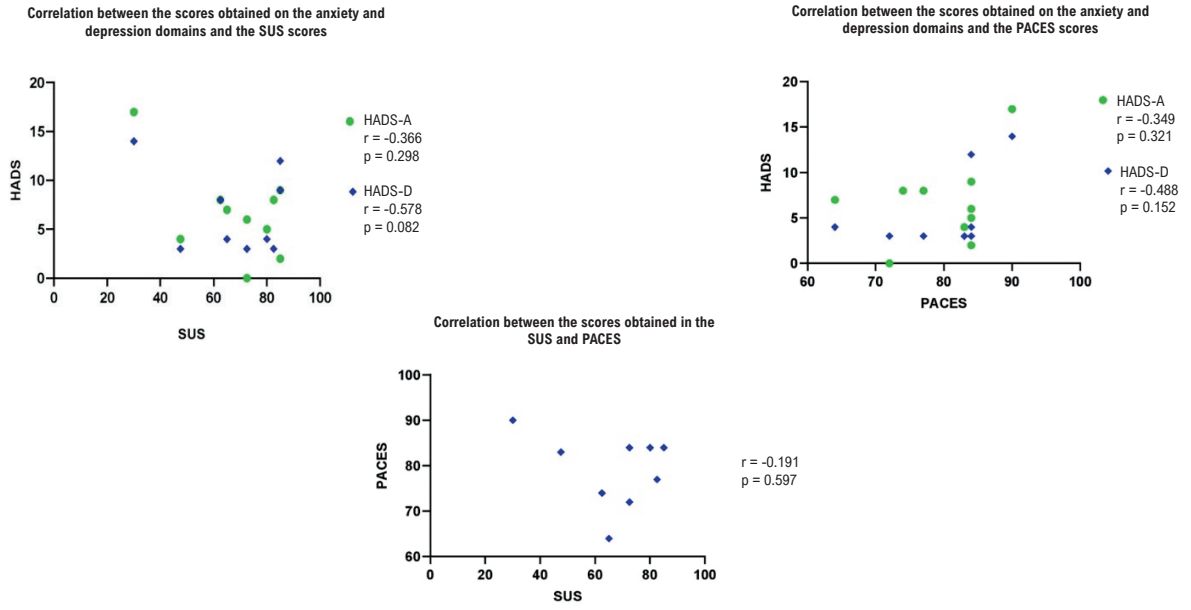

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HADS-A: Hospital Anxiety and Depression Scale – anxiety domain; HADS-D: Hospital Anxiety and Depression Scale – depression domain; SUS: System Usability Scale; PACES: Physical Activity Enjoyment Scale; r: Pearson's correlation coefficient; p: significance level (at 5%, p<0.05).

heart.[6] HF is characterized by cardiac dysfunction resulting from abnormalities in cardiac structure or function, leading to the heart's inability to maintain systemic perfusion adequately without the need for high ventricular filling pressures.[7,8] Even individuals with stable and well-compensated HF experience exercise intolerance as their primary symptom, which negatively impacts functional capacity, decreasing their independence in activities of daily living and worsening their quality of life.[9]

Cardiovascular rehabilitation (CVR) is an "activity necessary to ensure the best physical, psychological, and social conditions of individuals with cardiovascular diseases, preserving and improving their quality of life and decreasing risk factors".[10] CVR is an essential low-cost non-pharmacological treatment;[11] however, adherence to CVR programs remains a challenge,[12] requiring specific strategies to engage this population effectively.[13]

Despite growing research on the use of VR in rehabilitation programs, most studies focus on quantitative data and seldom assess patient satisfaction or the acceptance of such devices. Analyzing patients' perspectives, focusing on their experiences, needs, and the barriers they face when using digital interventions is crucial to understanding the use and effectiveness of technologies. Therefore, this study's objective is to assess the usability of VR exposure during cycle ergometer exercise among hospitalized HF patients.

Method

The Institutional Review Board at the Federal University of São Paulo (CAAE: 54896621.9.0000.5505) approved the research project.

This study was designed in two phases: a pilot study (first phase) and a randomized clinical trial (second phase). This article addresses only the first phase, which concerns a pilot cross-sectional study with a sample established according to studies addressing the same topic in the literature.[14-16] The randomized clinical trial will be conducted as a separate study.

The sample comprised patients with a clinical diagnosis of HF with left ventricular ejection fraction (LVEF) ≤ 50%, of both sexes, aged over 18 years, and hemodynamically stable (not presenting malignant ventricular arrhythmias or signs of low output in the

last 48 hours), who were medically cleared to begin rehabilitation, and signed a free and informed consent form. Patients with HF were consecutively recruited for the study based on predefined selection and inclusion criteria. Recruitment was conducted sequentially, wherein each eligible patient was invited to participate immediately upon meeting the criteria. All ten patients who were invited consented to participate, resulting in no refusals.

The participants were clinically examined, and their sociodemographic information, anamnesis, personal and family history, and medications were identified. Additionally, a physical examination and complementary exams were performed, followed by the administration of the Hospital Anxiety and Depression Scale (HADS).

The immersive virtual environment provided by the VZFit application (VirZoom, Inc.) was adopted for academic purposes, distinct from its commercial application. It was adapted for use with the Head-Mounted Display Oculus Quest 2 (Facebook Technologies Ltd., Menlo Park, CA, USA). In this study, a cycling route simulation was executed using a stationary bike synchronized with the application through a cadence sensor, as illustrated in Figure 1.

The participants performed the exercise while seated using a portable lower limb cycle ergometer, enabling them to better adapt to the pedals and avoid compensatory hip movements. They were instructed to rotate the pedal without load actively but at a comfortable speed for the maximum time tolerated using an immersive VR system.

The patients were monitored throughout the protocol with a digital sphygmomanometer, pulse oximetry, and a heart rate monitor. Additionally, they were instructed on the perceived exertion scale (modified Borg). Exercise should be interrupted at any time if a participant experienced diastolic blood pressure above 120 mmHg among normotensive individuals or 140 mmHg among hypertensive patients; systolic blood pressure persistently dropped more than 10 mmHg or markedly increased more than 200 mmHg; decreased heart rate; clinical manifestation of chest discomfort, ataxia, dizziness, pallor, cyanosis, pre-syncope, or dyspnea disproportionate to the intensity of effort—Borg modified for dyspnea or limb fatigue lower than 4;[17] had intolerance to the VR system; there was a failure in the monitoring system, or if the patient requested it to be interrupted.

After the intervention, the participants responded to the System Usability Scale (SUS) to check the system's usability and the Physical Activity Enjoyment Scale (PACES) to assess participants' satisfaction.

Figure 1 – Illustration of the activity with VR.
The illustration was created by a designer using the animation software Moho Pro (Smith Micro Software, Inc.). It visually represents the different stages of the intervention, including patient preparation, exercise execution, and monitoring. Source: the authors.

Statistical analysis

Statistical analysis included descriptive and inferential analyses performed with Statistical Package for Social Sciences (SPSS), version 25.0 (IBM Corp., Armonk, NY, USA). A significance level of 5% ($p<0.05$) was used. The methods followed Field's[18,19] approach. Descriptive analysis for quantitative variables included measures of central tendency (mean) and dispersion (standard deviation), while absolute and relative frequencies were calculated for categorical variables. Data normality was assessed through the Shapiro-Wilk test. Pearson's test, classified as parametric, was used for correlation analysis. The choice of a parametric test was based on the normality of the data. The correlation coefficient, 95% confidence interval, and p-values were calculated using the bias-corrected and accelerated bootstrap sampling method based on 2,000 samples. For effect size interpretation, Cohen's classification (1992) was applied, with the following criteria for the r coefficient and correlation coefficients: small (0.100 to 0.299), medium (0.300 to 0.500), or large (above 0.500). Considering the study's sample size, the correlations found were classified according to this reference, despite the observed effect.

Results

The results presented in Table 1 and Graphs 1, 2, and 3 show the sample's demographic and clinical characteristics and the correlations between the scores on the anxiety, depression, usability, and exercise enjoyment scales. Ten participants met the study's inclusion criteria. As shown in Table 1, the participants presented a very low LVEF and showed signs of congestion at admission.

Graphs 1 and 2 represent the correlation analysis of the scores obtained in the HADS with those obtained in the SUS and PACES using the Pearson's correlation test.

No statistically significant correlations were found between the scores obtained in the anxiety and depression domains and usability or physical activity enjoyment.

Discussion

Chronic diseases account for significant and alarming levels of morbidity. For this reason, different resources are needed to tackle this situation, and current technological advances can be introduced into healthcare for this purpose.[20] Many of the life dimensions of individuals affected by chronic diseases, such as cardiovascular diseases, are compromised beyond the biological aspect, i.e., the psychological dimension is likely also affected.[21]

Individuals with HF may often experience symptoms of depression and anxiety, which may further compromise their quality of life and activities of daily living,[17] worsening an already compromised baseline functional status; dyspnea has been reported to be strongly related to depression symptoms.[17] A prospective study addressing 103 patients with HF monitored in an outpatient clinic concluded that more than half of the individuals experienced anxiety (53.4%) or depression (52.4%) symptoms.[22] Mental health disorders, in general, tend to decrease quality of life and impact adherence to HF treatment. Studies show that depression, anxiety, and stress are associated with increased rates of HF-related hospitalization and mortality.[23] Although cognitive aspects were not assessed here, the literature indicates a prevalence of cognitive deficits among individuals with HF, which may also impair care management and treatment adherence.[24]

The correlation between anxiety and/or depression symptoms and exercise motivation is a psychological parameter seldom described in secondary prevention, considering that motivation possibly contributes to a differential effect on rehabilitation.[25] Therefore, the following question arises: What tools can be included in daily clinical practice to foster these individuals' interest and motivation?

Technological tools are diverse, and in our study, we focused on VR justified as a possible alternative to be offered to individuals in rehabilitation programs because with this tool, for example, we can customize scenarios and insert rewards—features that can impact incentivizing activities.[25] We observed that even with the tendency toward anxiety and depression in the sample, a favorable evaluation of the system's usability and exercise satisfaction was obtained. Technological tools for enhancing healthcare have been on the rise in recent years. Bergmann[26] utilized a VR system associated with a robotic gait device and observed that the combination of VR resulted in higher acceptability, increased motivation, reduced dropout rates, and longer training times than traditional rehabilitation. In a randomized pilot clinical trial, Bravo et al.[13] further showed that VR could effectively improve the outcomes of patients with ischemic heart disease, contributing to better physical fitness and quality of life. This finding underscores the potential of VR in fostering patient

Table 1 – Sample demographic and clinical characteristics.

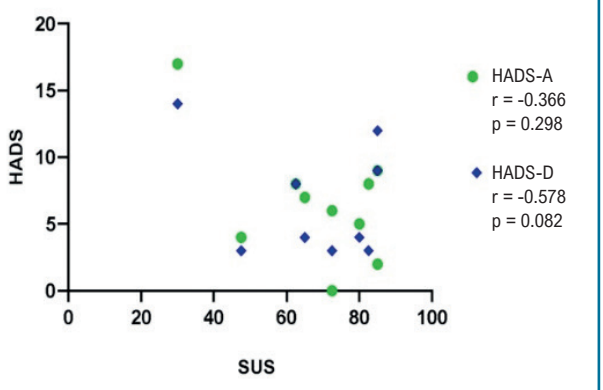
Age (years), mean (SD)	55.5 (11.3)
Sex, No. (%)	
Male	6 (60)
Female	4 (40)
Race, No. (%)	
Mixed race	**5 (50)**
Afro-descendant	**3 (30)**
Caucasian	**2 (20)**
Education, No. (%)	
Incomplete middle school	8 (80)
Complete middle school	1 (10)
Bachelor's degree	1 (10)
Comorbidities, No. (%)	
Systemic arterial hypertension	7 (70)
Brain stroke	3 (30)
Ex-smoker	3 (30)
Dyslipidemia	2 (20)
Chronic kidney disease	2 (20)
Atrial fibrillation	2 (20)
Hypothyroidism	2 (20)
Current smoker	2 (20)
Acute myocardial infarction	2 (20)
Cancer	1 (10)
Diabetes	1 (10)
Peripheral vascular disease	1 (10)
HF etiology, No. (%)	
Chagas	5 (50)
Ischemic	2 (20)
Undefined	3 (30)
LVEF, mean (SD)	27.8 (9.4)
NYHA, No. (%)	
I – No symptoms	5 (50)
II – Mild symptoms	5 (50)
Hemodynamic profile at admission, No. (%)	
B – Wet/warm	8 (80)
C – Wet/cold	1 (10)
L – Dry/cold	1 (10)
Hospitalization stays in days, median (IQR)	19 (15-34)
HADS, mean (SD)	
Anxiety	6.6 (4.6)
Depression	6.3 (4.1)
SUS. mean (SD)	68.2 (17.8)
PACES. mean (SD)	79.6 (7.7)

SD: Standard Deviation; HF: Heart Failure; LVEF: Left Ventricular Ejection Fraction; NYHA: New York Heart Association; HADS: Hospital Anxiety and Depression Scale; SUS: System Usability Scale; PACES: Physical Activity Enjoyment; IQR: intervalo interquartil. Source: the authors.

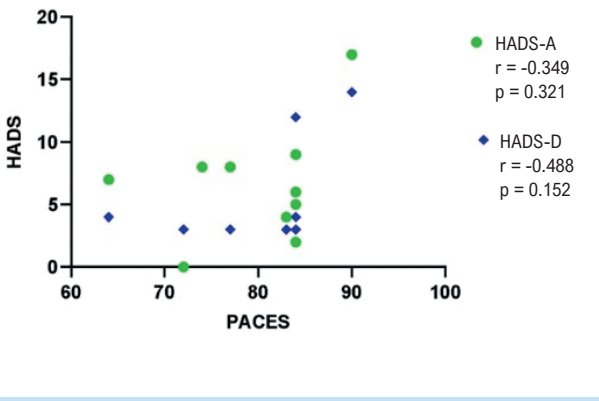
engagement and optimizing rehabilitation protocols, making it a promising pathway for future cardiac rehabilitation programs.

VR strategy as a motivational factor has aroused interest in rehabilitation programs in different specialties, as motivation may be related to better functional clinical outcomes. In a review conducted by Rutkowski et al.[27] encompassing 17 studies with patients in neurological, orthopedic, geriatric, and pediatric rehabilitation programs, it was observed that VR may be advantageous in rehabilitating upper limb dysfunctions and may improve balance in neurological patients.

In our study, an immersive VR system associated with exercise was used in hospitalized patients with HF. Immersive VR is a technology that provides a more realistic environment design and object tracking with virtual interaction and real-time feedback. In a study conducted by Groninger et al.,[28] immersive VR was shown to be an effective non-pharmacological adjunctive intervention for pain control in hospitalized HF patients. In rehabilitation programs, immersive and semi-immersive VR use in exploratory upper limb movement tasks facilitated both upper limb motor performance and cognitive recovery in acute, subacute, and chronic stroke rehabilitation. The results also showed perceived satisfaction by patients and improved attendance in rehabilitation programs. During the intervention, no participants reported significant side effects such as dizziness or cybersickness. However,



Graph 1 – Correlation between the scores obtained on the anxiety and depression domains and the SUS scores.
HADS-A: Hospital Anxiety and Depression Scale—anxiety domain; HADS-D: Hospital Anxiety and Depression Scale—depression domain; SUS: System Usability Scale; r: Pearson's correlation coefficient; p: significance level (at 5%, p<0.05). Source: the authors.



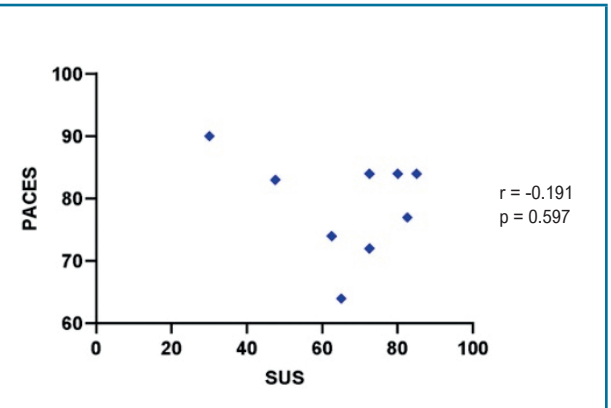
Graph 2 – Correlation between the scores obtained on anxiety and depression domains and the PACES scores.
HADS-A: Hospital Anxiety and Depression Scale – anxiety domain; HADS-D: Hospital Anxiety and Depression Scale – depression domain; SUS: System Usability Scale; PACES: Physical Activity Enjoyment Scale r: Pearson's correlation coefficient; p: significance level (at 5%, p<0.05). Source: the authors.

future studies should explore the prevalence of these side effects in large samples.

Digital health ranges from healthcare network management systems to tools used in patient care.[29] According to the Brazilian Ministry of Health's[29] digital health policy, appropriate strategies are needed to implement technological tools to improve healthcare delivery, ensuring favorable outcomes concerning the qualification and training of workers and enabling patients to become protagonists in their treatment. Thus, technological resources must be accessible in order to be introduced in clinical practice and play an effective role in healthcare, especially inpatient rehabilitation programs.[30]

There are diverse technological tools, and the studies addressing VR are heterogeneous regarding the protocols and types of systems adopted (non-immersive, semi-immersive, and immersive). Usability evaluation provides valuable information about acceptability and satisfaction, allowing for predictions regarding whether the products and/or systems will be used by patients. In this study, we focused on VR as a feasible alternative for individuals attending rehabilitation programs, and it is the first study using immersive VR associated with physical activity among HF inpatients. According to what Birckhead et al.[31] propose, we sought to assess the usability of VR and correlate it with the participants' anxiety and depression profiles and their level of physical activity enjoyment.

A major challenge in implementing these strategies is to ensure good engagement of the individual and adherence to exercise programs. In the literature, the main barriers to low participation and adherence to CVR programs are advanced age, low socioeconomic status, female sex, depression, financial or medical concerns, low functional capacity, multiple comorbidities,[32] functional dependence, and patients' perception of the program as inconvenient and unnecessary. Recent research suggests that digital



Graph 3 – Correlation between the scores obtained in the SUS and PACES.
SUS: System Usability Scale; PACES: Physical Activity Enjoyment Scale; r: Pearson's correlation coefficient; p: significance level (at 5%, p<0.05). Source: the authors.

health interventions can play an important role in primary and secondary prevention, supporting rehabilitation and self-management as potential facilitators in health interventions and motivational agents.[33]

The difference between this study and those in the current literature lies in the use of immersive VR and the fact that it was conducted in CVR phase I, i.e., the sample addressed here presents a more severe and complex profile with an average LVEF of 27.8%. According to the Brazilian Guidelines on Chronic and Acute HF,[8] late mortality (one year) among individuals with Heart Failure with Reduced Ejection Fraction (HFrEF) is 8.8%. Tsukamoto et al.[34] prospectively assessed changes in LVEF one year after discharge and the outcomes of patients hospitalized with HFrEF and Heart Failure with Preserved Ejection Fraction (HFpEF) and found that HFrEF was associated with a poor prognosis and increased risk of mortality from various causes. CVR among patients with HFrEF was associated with increased quality of life and exercise capacity, besides fewer hospitalizations due to all causes.[35,36] Thus, the benefits of CVR show the relevance of studies addressing and developing strategies to improve patient adherence to such programs.

Although the literature presents evidence of the use of VR in rehabilitation, most studies focus on clinical outcomes, seldom addressing the systems' usability. Usability evaluation provides essential information about acceptability and satisfaction, allowing to predict which products and systems patients will effectively adopt. Although there are no specific scales for evaluating the usability of VR systems, the SUS is widely adopted, and scores above 68 are generally considered indicative of good usability.[37]

A negative correlation was found between participants' anxiety and depression symptoms and system usability and enjoyment with physical activity associated with VR. However, this correlation was not statistically significant. Some studies indicate that VR has the potential to reduce stress, anxiety, and depression symptoms among patients attending rehabilitation programs.[38,39]

This study represents a significant advancement in the incorporation of technology into CVR during the hospital phase for HF patients, potentially opening up avenues for further exploration in this field. The increasing availability of VR systems offers an opportunity for numerous patients enrolled in rehabilitation programs to enjoy a stimulating and diverse experience. Despite the widespread recommendation of CVR for HF patients, the ongoing challenge of low adherence rates highlights the necessity for innovative solutions. The expansion of VR in rehabilitation emerges as a promising approach, complementing conventional CVR methods. Grounded in multidisciplinary practices, VR enables personalized adaptations and may offer a favorable cost-benefit ratio, although additional investigation is required.

Hard technologies, namely material resources such as equipment and devices, are constantly present in our lives, whether to optimize daily tasks, communicate, or entertain. It has been observed that these resources can be within the realm of healthcare, but technology should be seen as a "means," and this "means" should be tailored to individuals' subjectivity, considering not only their biological aspects regarding their health and disease process but also their anthropological and psychosocial aspects. Understanding users' acceptability from the perspective of their psychosocial dimensions, beyond just clinical outcomes, can assist in the development and use of technological tools that may be accepted by the population, thus providing new possibilities for healthcare.[40]

Limitations

Some limitations of this study must be recognized. First, this is a pilot study with a small sample size. Second, the conclusions about usability and satisfaction are based on a single session. Furthermore, the intensity of effort was not measured objectively, as it was monitored by the subjective perception of the exertion scale (Borg) and not by more precise tools.

Conclusions

This pilot study is an important step toward using VR in hospital CVR among patients with HF. The results show that the system presents good usability levels, and the participants enjoyed exercising with VR. However, no statistically significant correlations were found between anxiety and depression symptoms and system usability. Hence, these results suggest that VR has the potential to be a valuable complementary tool for rehabilitation programs, but further research is needed to address larger samples at different stages of CVR to validate these findings. The successful introduction of technologies such as VR into clinical practice may represent a significant advance in the treatment and quality of life of HF patients.

Furthermore, this study paves the way for the next research phase, which will involve a randomized clinical trial with a larger number of participants and the inclusion of clinical outcomes. This next step is expected to provide additional insights into the effectiveness of VR as a rehabilitation tool for patients with HF. The project for the next phase is registered in the Brazilian Clinical Trials Registry (ReBEC, *Registro Brasileiro de Ensaios Clínicos*) under RBR-4hrmkz.

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Author Contributions

Conception and design of the research: Costa AS, Barbosa CB, Guizilini S, Santos VR, Moreira RSL; acquisition of data: Costa AS, Barbosa CB; analysis and interpretation of the data: Costa AS, Barbosa CB, Guizilini S, Moreira RSL; statistical analysis: Santos VR, Moreira RSL; writing of the manuscript: Costa AS, Barbosa CB, Moreira RSL; critical revision of the manuscript for intellectual content: Costa AS, Barbosa CB, Guizilini S, Santos VR, Miura CR, Junior M, Silva AG, Moreira RSL.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Study Association

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Ethics Approval and Consent to Participate

This study was approved by the Ethics Committee of the Universidade Federal de São Paulo under the protocol number 54896621.9.0000.5505. All the procedures in this study were in accordance with the 1975 Helsinki Declaration, updated in 2013. Informed consent was obtained from all participants included in the study.

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