

Impact of assisted exercises on skeletal muscle oxygenation levels in men with acutely decompensated heart failure

Olga Kisiel^{1,B,D}, Agnieszka Ewa Siennicka^{2,C,D}, Krystian Josiak^{1,3,C,E}, Robert Zymliński^{3,B,E}, Waldemar Banasiak^{1,E,F}, Kinga Węgrzynowska-Teodorczyk^{1,4,A–D,F}

¹ Centre for Heart Diseases, 4th Military Hospital, Wrocław, Poland

² Department of Physiology and Patophysiology, Wrocław Medical University, Poland

³ Institute of Heart Diseases, Wrocław Medical University, Poland

⁴ Faculty of Physiotherapy, University of Health and Sport Sciences in Wrocław, Poland

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;

D – writing the article; E – critical revision of the article; F – final approval of the article

Advances in Clinical and Experimental Medicine, ISSN 1899–5276 (print), ISSN 2451–2680 (online)

Adv Clin Exp Med. 2023;32(2):211–218

Address for correspondence

Agnieszka Ewa Siennicka

E-mail: agnieszka.siennicka@umw.edu.pl

Funding sources

The research was financially supported by the National Science Centre (grant No. Sonata 6 UMO-2013/11/D/NZ7/00922).

Conflict of interest

None declared

Received on February 22, 2022

Reviewed on August 4, 2022

Accepted on August 23, 2022

Published online on November 14, 2022

Cite as

Kisiel O, Siennicka AE, Josiak K, Zymliński R, Banasiak W, Węgrzynowska-Teodorczyk K. Impact of assisted exercises on skeletal muscle oxygenation levels in men with acutely decompensated heart failure. *Adv Clin Exp Med*. 2023;32(2):211–218. doi:10.17219/acem/152930

DOI

10.17219/acem/152930

Copyright

Copyright by Author(s)

This is an article distributed under the terms of the Creative Commons Attribution 3.0 Unported (CC BY 3.0) (<https://creativecommons.org/licenses/by/3.0/>)

Abstract

Background. The complex clinical status of modern day patients hospitalized due to acute heart failure (AHF) results from their advanced age, comorbidities, frailty, heart failure symptoms (including massive swelling of the lower limb), and dramatic reduction of exercise tolerance. Hence, there is a need to implement physiotherapeutic procedures as early as possible, aiming to both accelerate the restoration of clinical stabilization and prevent post-hospital disability.

Objectives. We investigated whether assisted lower limb exercises have an impact on perfusion and oxygenation in skeletal muscle and if they are feasible in patients with AHF.

Materials and methods. We examined 34 men (age: 66 ± 11 years; left ventricular ejection fraction (LVEF): $34 \pm 11\%$; clinical presentation: 31 wet-warm and 3 wet-cold). The intervention (carried out on the 2nd day of hospitalization) included: 1) a 3-minute rest period; 2) an exercise phase (45 repetitions of assisted flexion and extension of the lower limb; and 3) a 10-minute relaxation period. We analyzed blood pressure (BP), heart rate (HR), respiratory rate (RR), tissue oxygenation (reflected by oxygen saturation measured with a pulse oximeter), and changes in peripheral tissue perfusion (reflected by the tissue oxygenation index (TOI) measured with near-infrared spectroscopy (NIRS)).

Results. The hemodynamic parameters (both Δ HR and Δ systolic BP) and oxygen saturation did not change (all $p > 0.05$), whereas the RR declined ($p < 0.001$). The exercises improved venous outflow (reflected by decreased oxygenated, deoxygenated and total hemoglobin, all $p < 0.05$) and increased peripheral tissue perfusion, as reflected by the TOI ($p < 0.05$). The patients reported relief and lack of dyspnea during and after the assisted exercises.

Conclusions. The physiotherapeutic intervention improved both venous outflow and muscle oxygenation in men with AHF. The presented protocol was safe, feasible and well-tolerated, and resulted in relief for the patients. We believe that such procedures might be recommended for the initial period of rehabilitation in this challenging subgroup of patients.

Key words: physiotherapy, heart failure, near-infrared spectroscopy, skeletal muscle oxygenation

Background

Morbidity and mortality due to heart failure increase every year, affecting more than 10% of people over the age of 70.¹ A fundamental aspect of heart failure is periods of exacerbation, known as cardiac decompensation or acute heart failure (AHF).² Efficient therapeutic options for patients with AHF have been evolving over the last 2 decades and have resulted in an extension of life expectancy and significant changes to their clinical profile compared to 20 years ago. Therefore, patients hospitalized for AHF are now older, have more comorbidities, such as frailty syndrome, and a worse prognosis.^{3–5}

It is noteworthy that hospitalization of patients due to AHF may have additional negative consequences, such as the so-called “post-hospital syndrome”, which is associated with an increased risk of disability.^{6,7} Studies have demonstrated that up to 60% of AHF patients develop hospital-acquired disability, which is associated with a worse clinical outcome.⁸

Hospitalization due to AHF is associated with extended time spent lying in bed, especially for patients who are unable to walk independently. As a result, some experience a new major physical disability following hospital discharge.^{9,10}

The data suggest that exercise and early rehabilitation protocols applied during acute hospitalization may prevent functional and cognitive decline in older patients. Additionally, these treatments are associated with shorter hospital stay and lower costs.^{11–13} It is very likely that physiotherapeutic interventions implemented as early as possible during hospitalization due to AHF may mitigate these unfavorable outcomes.^{10,14–16} However, cardiac physiotherapy implemented early in AHF has not been well established. It is generally accepted that such patients require special physiotherapeutic care.^{17,18}

In AHF, the patient’s clinical picture can vary greatly. One major symptom is massive swelling of the lower limbs, which limits the patient’s mobility or even makes it impossible to move, forcing the patient to remain in a lying or sitting position. Additionally, AHF is associated with an increased level of fatigue and dyspnea associated with fear of exacerbation of symptoms during physical exercise.¹⁸

Having these considerations in mind, we selected assisted exercises for being investigated in this study. Importantly, there is currently no available literature describing the feasibility and effects of assisted exercises in patients in the acute stages of heart failure.

Objectives

The aim of this study was to evaluate the feasibility of assisted lower limb exercises and to examine their impact on the levels of perfusion and oxygenation in the skeletal muscles of patients with AHF. We decided to analyze this

at 3 levels: level related to the patient’s subjective perception, hemodynamic level (heart rate (HR) and blood pressure (BP) response) and tissue level (i.e., tissue oxygenation).

Materials and methods

Study design and participants

The study included patients with AHF. Acute heart failure was defined according to the current 2021 European Society of Cardiology (ESC) Guidelines² as a rapid or gradual onset of symptoms and/or signs of heart failure requiring unplanned hospitalization of the patient. The use of an intravenous loop diuretic and/or vasodilator was not necessary to participate in this study.

This study was registered at Clinicaltrials.gov (ID No. NCT03102164). All study participants provided written informed consent to participate in the study.

Patients were excluded if they met any of the following exclusion criteria: acute coronary syndrome, bacterial infection, pre-existing chronic respiratory failure, need for invasive mechanical ventilation, significant arrhythmia (arrhythmia that was hemodynamically unstable and/or needed urgent targeted treatment) or conductivity disorders, anemia (hemoglobin <9 g%), active neoplastic process, liver injury (aspartate aminotransferase (AST) or alanine aminotransferase (ALT) more than 3 times the reference level), or chronic kidney failure with creatinine clearance <30 mL/min. Patients with acute deep vein thrombosis or significant orthopedic diseases of the lower limb were also excluded. Finally, patients with massive swelling and/or shortness of breath making it impossible to lie down were excluded.

Procedure and exercise settings

Patients were recruited into the study by doctors who exercised medical supervision of the rehabilitation process. A total of 34 men with AHF participated in the study. The clinical characteristics of the study group are presented in Table 1.

The tests were carried out in the patient’s room at the cardiology department on their 2nd day of hospitalization. No noninvasive ventilation was used during the study.

The study protocol was divided into 3 stages:

1) Recording of the resting parameters (3 min), during which the accuracy of measurement and recordings were simultaneously monitored.

2) Assisted exercise phase. Assisted exercise refers to exercise in which a physiotherapist alone facilitates the movement by relieving the exercised limb. The movement is performed with a minimal use of the patient’s muscle strength.¹⁹ During this phase, the physiotherapist performed 45 repetitions of assisted exercise, involving flexion of the studied lower limb at the knee and hip joints. For the hip joint, the angle of flexion was in the 45–90°

Table 1. Clinical characteristics of the study group and the pharmacological treatment used at the time of the inclusion in the study

Clinical variable	Men with AHF (n = 34)
Age [years]	66 ± 11
BMI [kg/m ²]	29.7 ± 6.4
AHF etiology, ischemic, n (%)	18 (53)
HFrEF, n (%)	23 (68)
HFmEF, n (%)	6 (18)
HFpEF, n (%)	5 (14)
LVEF [%]	33.8 ± 11
LVEDD [%]	64 ± 11.4
NYHA IV, n (%)	34 (100)
SBP [mm Hg]	128 ± 21
SpO ₂ [%]	95 ± 2
Hemoglobin [g/dL]	13.2 ± 2
Creatinine [mg/dL]	1.5 ± 0.8
NTproBNP [pg/mL]	6522 ± 4750
PaO ₂ [mm Hg]	67 ± 11
MR (n, %)	
Mild	23 (68)
Moderate/severe	11 (32)
Hypertension, n (%)	20 (59)
Diabetes mellitus, n (%)	17 (50)
Chronic obstructive pulmonary disease, n (%)	6 (18)
ICD, n (%)	9 (27)
CRT-D, n (%)	5 (15)
CABG, n (%)	4 (12)
AF, n (%)	21 (62)
QRS > 120, n (%)	13 (38)
LBBD, n (%)	5 (15)
Clinical presentation (n, %)	
Wet and warm	31 (91)
Wet and cold	3 (9)
Peripheral congestion	29 (85)
Pulmonary congestion	34 (100)
Pharmacological treatment (n, %)	
ACE-I and/or ARB	29 (85)
β-blocker	34 (100)
Digoxin	3 (9)
Furosemide	34 (100)
Vasodilator	23 (68)
Dobutamine	1 (3)
Noradrenaline	0 (0)

BMI – body mass index; AHF – acute heart failure; HFrEF – heart failure with reduced ejection fraction; HFmEF – heart failure with mid-range ejection fraction; HFpEF – heart failure with preserved ejection fraction; LVEF – left ventricular ejection fraction; LVEDD – left ventricular end-diastolic diameter; NYHA – New York Heart Association; AS – aortic stenosis; SBP – systolic blood pressure; SpO₂ – blood oxygen saturation; NTproBNP – N-terminal pro B-type natriuretic peptide; PaO₂ – partial pressure of oxygen in arterial blood; MR – mitral regurgitation; CRT-D – cardiac resynchronization therapy defibrillator; CABG – coronary artery bypass graft; AF – atrial fibrillation; LBBD – left bundle branch block; ACE-I – angiotensin-converting enzyme inhibitor; ARB – angiotensin receptor blockers; ICD – implantable cardioverter-defibrillator; QRS – QRS complex (Q wave R wave S wave).

range, and the knee joint was expected to be at an obtuse angle of 90–100° (heel raised above the knee). The exercise duration was approx. 1.5 min.

3) Relaxation phase. Relaxation phase comprised of a 10-minute measurement. Care was taken to ensure the patient lay still during this time and does not make any movements.

Variables and data sources

The impact of the exercises on the following factors was assessed:

1) Subjective feelings of the patient. After the exercise, the patient was asked to provide information (feedback) as to whether the exercise: affected their discomfort levels, tissue tension and lower limb pain (unchanged ↔/increased ↑/decreased ↓); provoked or increased their feeling of breathlessness (yes/no).

2) Hemodynamic parameters. Each examination was conducted with supervision and monitoring of the following hemodynamic parameters: HR, BP and respiratory rate (RR).

3) Tissue oxygenation. In addition to standard saturation assessment measured with a pulse oximeter, near-infrared spectroscopy (NIRS) was used to assess tissue oxygenation. This was important considering the reduced peripheral perfusion and frequent swelling of the lower limbs experienced by patients with AHF. Near-infrared spectroscopy is a tool used for continuous noninvasive monitoring of changes in peripheral tissue perfusion.²⁰ Near-infrared spectroscopy is based on the absorption of near-infrared photons by chromophores (e.g., hemoglobin). Differences in the intensity of NIRS absorption by oxygenated and reduced hemoglobin were analyzed using algorithms based on the Beer–Lambert law. The NIRS light emitted by the sensor's diode penetrated locally into the tissue underneath, and the hemoglobin level in the microcirculation was measured with 2 detectors.^{21–23} The photosensor was placed on the subject's quadriceps muscle, 1/3 of the way to the proximal lateral head. The distance between the sensors in the photosensor was 4 cm; thus, the sensor's penetration depth was up to 4 cm. Commonly, NIRS is used to check the dynamic balance between the delivery and extraction of oxygen in the tissue during surgery or exercise.²⁰ We used NIRS to assess leg muscle perfusion and to indirectly determine venous outflow during the assisted exercises. The following parameters were measured and subsequently analyzed: tissue oxygenation index (TOI, i.e., the percentage ratio of oxygenated hemoglobin to total hemoglobin) and changes in oxygenated hemoglobin ($\Delta\text{O}_2\text{Hb}$), deoxygenated hemoglobin (ΔHHb) and total hemoglobin ($\Delta\text{total Hb}$).

The research was carried out as part of the Sonata 6 UMO-2013/11/D/NZ7/00922 research grant awarded by the National Science Centre, Kraków, Poland. It was conducted in accordance with the Declaration of Helsinki and approved by the Bioethics Committee of Wrocław Medical University, Poland (approval No. 204/2015).

Statistical analyses

Continuous variables with normal distribution were described using mean \pm standard deviation ($M \pm SD$). Variables with skewed distribution were described as medians with upper and lower quartiles. Categorical variables were given as numbers and percentages. In the case of a nonparametric test for 2 trials of dependent variables, a Wilcoxon signed-rank test was used to analyze changes in the hemodynamic parameters before and after the exercise. The differences between particular phases of exercise were analyzed using the Friedman's analysis of variance (ANOVA) with determination of the Kendall's compliance factor. A value of $p < 0.05$ was considered statistically significant. Statistical analyses were performed using Statistica v. 12 (StatSoft, Tulsa, USA).

Results

The assisted exercises were well tolerated by the patients. After the series of 45 repetitions of the assisted exercise, BP and HR remained unchanged, while a decrease in RR was observed (Table 2). No adverse symptoms were reported during the exercises or directly after (Table 3).

The exercises did not change the saturation levels ($p = 0.11$); their value remained at 95% (93–96%). The percentage changes in selected oxygenation parameters of the quadriceps muscle during the various phases of testing are presented in the Figures. Figures 1–4 present the values of changes in the ΔO_2Hb , ΔHHb , $\Delta total\ Hb$, and TOI at the following test phases: at rest, during the assisted

exercise, and after the 1st and 10th min of relaxation following exercise completion.

A decrease in the level of oxygenated hemoglobin was achieved as a result of the assisted exercises. In the 1st minute of relaxation, an upward trend was observed, only to return to the resting value in the final phase (Fig. 1). A significant decrease in the levels of deoxygenated hemoglobin and total hemoglobin was achieved as a result of the assisted exercises. In the 1st minute of relaxation, an upward trend was observed, only to return to the resting value in the final phase (Fig. 2,3). After performing the assisted exercises, a slight increase in oxygenation in the quadriceps muscle of the thigh was observed in the later phase of rest ($p < 0.03$) (Fig. 4).

Discussion

The increased frequency of peripheral swelling and resting dyspnea during a decompensated heart failure episode significantly limits the individual's ability to independently perform basic activities. Consequently, the management of AHF by a physiotherapist remains an ongoing challenge.

This research demonstrated that the assisted exercises studied were safe and accepted by AHF patients. Also, no adverse symptoms were observed. The majority of patients reported relief due to reduced discomfort and lower tissue tension in the lower limb. We also observed a decrease in the oxygenated hemoglobin, deoxygenated hemoglobin and total hemoglobin levels, accompanied by a slight increase in oxygenation in the quadriceps muscle of the thigh in the later phase of rest.

Table 2. Hemodynamic parameters before and after assisted exercise

Parameters	Resting median (upper-lower quartile)	After exercise median (upper-lower quartile)	p-value
SBP [mm Hg]	117 (101–136)	115 (100–133)	0.068
DBP [mm Hg]	71 (65–80)	71 (63–80)	0.088
HR [beats/min]	88 (65–99)	86 (66–94)	0.82
RR [breaths/min]	22 (20–26)	20 (20–24)	0.0002

SBP – systolic blood pressure; DBP – diastolic blood pressure; HR – heart rate; RR – respiratory rate.

Table 3. Subjective feelings of increased breathlessness or discomfort in the lower limb following exercise

Subjective feelings of symptoms	Answer	Patients (n (%))
Increased feelings of breathlessness	yes	5 (15) There was a slight difficulty at the beginning (breath holding or shallow breathing), which passed after a few repetitions and stabilized in the correct respiratory rhythm, coordinated with the movement of the lower limb
	no	29 (85)
Discomfort, tissue tension or pain in the lower limb	unchanged	10 (29) (6 of these patients had peripheral congestion)
	increased	0
	decreased	24 (71) (23 of these patients had peripheral congestion)

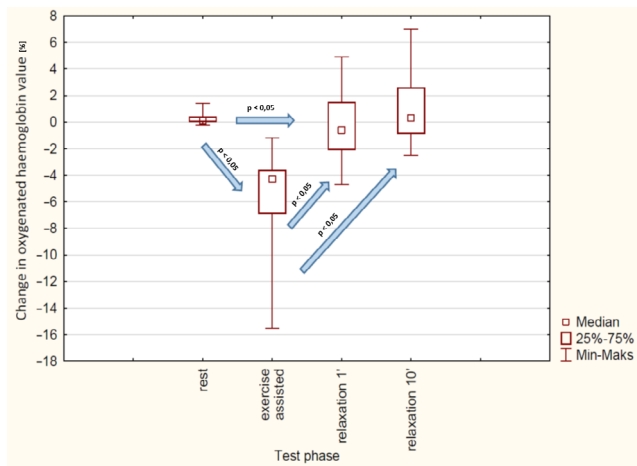


Fig. 1. Changes in oxygenated hemoglobin levels at different phases of the test

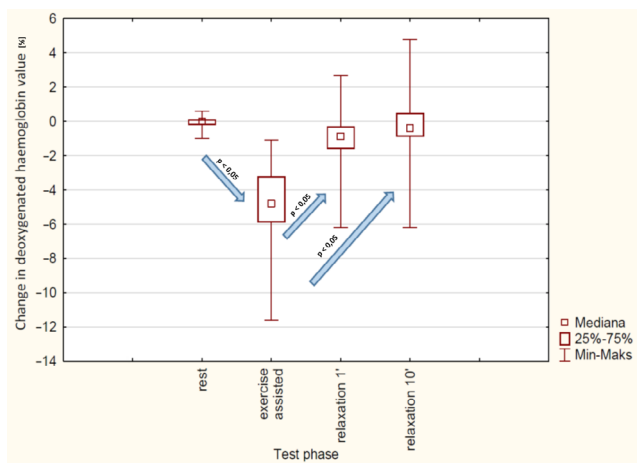


Fig. 2. Changes in deoxygenated hemoglobin levels at different phases of the test

Most patients were of the warm-wet profile (i.e., with peripheral stagnation and lower limb swelling), which is a group of patients to which these exercises are dedicated.

Additionally, we showed that the assisted exercises applied in this study are safe because they do not adversely affect the hemodynamic parameters (no changes in HR and RR). Unfavorable tendencies of decreased systolic BP or HR changes were not observed; these have an adverse impact on the prognosis in AHF.^{24,25} In evaluating the supply and use of oxygen by the skeletal muscles, we used NIRS, whose suitability has previously been demonstrated.^{26–28} Near-infrared spectroscopy has commonly been used to evaluate the dynamic balance between the delivery and extraction of oxygen in the tissue during surgery or exercise.^{20,29}

In a study by Belardinelli et al., changes in skeletal muscle oxygen saturation were evaluated during incremental exercise, both in patients with chronic heart failure (CHF) and in healthy subjects. It was observed that patients with CHF had reduced muscle oxygenation during exercise at any level of intensity compared to the control group.

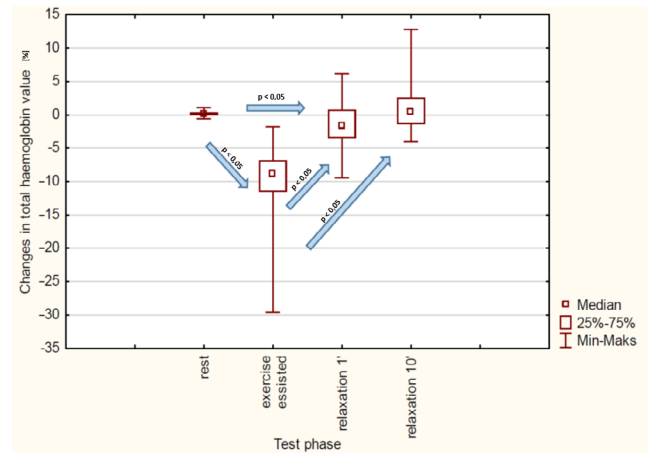


Fig. 3. Changes in total hemoglobin levels at different phases of the test

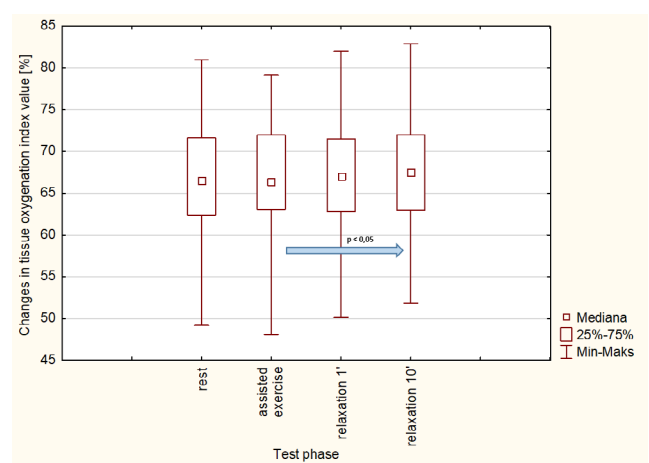


Fig. 4. Changes in tissue oxygenation index levels at different phases of the test

Additionally, patients with CHF had earlier acceleration in muscle deoxygenation, indicating a premature onset of anaerobic metabolism.^{30,31} Although the abovementioned publications evaluated lower limb skeletal muscle oxygenation in patients with heart failure, several disparities prevent us from comparing them with our results. The study by Belardinelli et al. involved patients with stable heart failure (New York Heart Association (NYHA) class II), whereas our project included subjects with AHF (NYHA class IV). Moreover, the studies differ in the type of exercise analyzed: dynamic exercise with a constant or increasing workload of several minutes on an ergometer cannot be compared with assisted exercises performed in clinically unstable patients. Assisted exercises last approx. 2 min and are performed by a physiotherapist, with minimal work performed by the patient.³⁰ We were unable to identify any studies in the available literature that had evaluated the impact of assisted exercises on the level of skeletal muscle oxygenation in patients with AHF. Thus, our results cannot be directly compared with the results of other studies.

The purpose of using NIRS in our study was not to assess oxygen extraction and metabolism, but blood flow and fluid distribution in the venous circulation, as well as to evaluate perfusion changes in the lower limb muscles under the influence of elevation and assisted movement. The NIRS tissue oxygen saturation measurement is made on a mixture of both venous and arterial blood with a mean ratio of 70% venous to 30% arterial. It has been empirically determined that the same mean ratio of 70% venous to 30% arterial blood volume applies to the whole body.³² This suggests that increased venous outflow from the peripheral tissues leads to a reduction in peripheral stasis, which may contribute to relief of the right ventricle. We can also assume that an increased venous outflow results in a better outflow of metabolites (such as H^+ , lactate, and prostaglandins PGE2 and PGF1), which may in turn positively affect a response from the ergoreceptors.³³ In the pathogenesis of heart failure symptoms, an increased response from the ergoreceptors is of major importance. It causes increased stimulation of the sympathetic nervous system, increased peripheral resistance, excessive ventilation, and increased dyspnea.³⁴

In our study, we observed increased venous outflow as a result of the assisted exercises with elevation of the lower limbs taken into account; however, the exercises did not (as one might expected) increase dyspnea in patients. On the contrary, the RR decreased. Based on these results, we can assume that the increased outflow of venous blood may contribute to an improvement in outflow of metabolites, reduction of the ergoreflex, and, consequently, reduction of sympathetic activation and dyspnea.

Patients with CHF have a decreased functional efficiency due to age, comorbidities and skeletal muscle dysfunction.^{35–37} Additionally, frailty syndrome, a consequence of decompensation, hospitalization and bed rest, leads to a sharp worsening of functional deficits, disease progression and a poorer prognosis.^{4,5} In order to increase their chances of returning to baseline functional physical fitness or to minimize the deficits resulting from AHF, it is necessary to start the rehabilitation as soon as possible.^{15,38}

The assumption of our research was to commence physical exercises, making it the first step as an introduction to the rehabilitation program of patients who are weak and bed-bound, helping them regain independence and mobility. Providing a uniform rehabilitation program and simple recommendations during an AHF episode is not possible. This is due to the varied clinical picture and diverse decompensation etiologies of the underlying disease or comorbidities.^{5,39,40}

Patients with AHF are often placed in intensive cardiac supervision wards where their rehabilitation commences; this resembles early mobilization of patients staying in the intensive care unit (ICU). It involves a gradual increase in functional activities, beginning with passive and active assisted exercises while the patient is lying

in bed, through active exercises in a sitting and standing position, progressing to walking in one spot, and then gait walking.^{16,41–43} Taking into account the absolute contraindications to exercise, the physiotherapist should develop an individualized, monitored and supervised rehabilitation program.^{17,40,44}

When choosing exercises for our research, the following principle was adopted: the more severe the heart failure, the lower the intensity and duration of exercise, and the higher the exercise frequency. Assisted exercises have been included in the Polish “HF model” of cardiac rehabilitation of patients with AHF.⁴⁰

In order to prevent progressive impairment of numerous body functions, Massimo Piepoli, an expert on heart failure and then the Chairman of the European Guidelines on cardiovascular disease prevention in clinical practice, has been recommending early mobilization of patients for years. Following a period of immediate threat and clinical instability, he encourages simple and slow movements performed as soon as possible.¹⁷ Piepoli emphasizes the important role of early activation of patients after stable clinical AHF status has been achieved. Exercises should be individualized based on simple movements, engaging body weight only.^{17,37}

Researchers have demonstrated the safety and efficacy of multidomain rehabilitation, which improves physical function and shortens rehospitalization. In their studies, they included independent and mobile patients who could walk at least 4 m at enrollment, were functionally independent before admission and were expected to be discharged from hospital.^{13,14} In the REHAB-HF project and in a multi-center study by Kitzman et al., the 30-minute rehabilitation sessions commenced in the hospital during AHF and continued at home and in the outpatient clinic for the next 12 weeks.^{14,45,46}

Our research stems from practice and from the daily needs of those working with elderly patients with disabilities who are bed-bound in hospital with severe disease symptoms. It was challenging to decide which exercises to start off with, and how to perform them or to estimate which groups of patients will benefit from them the most. In this project, we wanted to determine whether early activation is safe, if it has a positive impact on the patient's well-being, and, above all, whether it has an objective, measurable impact on the oxidation of skeletal muscles during a decompensated heart failure stage.

During AHF, patients often experience massive swelling associated with an increased tension of the skin integument of the entire lower limb, occasionally expanding the skin pores through which serous fluid may seep out. These symptoms are often accompanied by pain and discomfort, which hinder or prevent independent, active movements of the lower limb. With these ailments and our own experiences in mind, assisted exercises were selected. These types of exercises do not require effort from the patient or significant involvement of their own

muscles. Furthermore, during the early period of the disease, assisted exercises intend to gradually introduce other physiotherapeutic activities to the exercise therapy program with greater patient involvement. The additional benefit of assisted exercises is the reduction of risks involving thromboembolism and the reduction or prevention of edema.^{47,48} Peripheral edema of the lower extremities occurs in more than 50% of patients with stable heart failure and in about 75% of patients with decompensated heart failure.^{49,50} The role of assisted exercises was to enhance flow in the venous vascular bed by raising the heel and assisting the outflow of accumulated fluid, which can reduce stasis of the peripheral circulation.

When assessing oxygenation of the quadriceps muscle as a reaction to the exercises and in the rest phase 10 min after the end of the exercise, we observed a slight increase in the TOI. This is certainly a beneficial effect that requires further in-depth research. We presume that the improvement in venous outflow contributed to an increase in the arteriovenous difference and increased blood flow and oxygenation throughout the muscles.

The assisted lower limb movements also helped reduce the pain connected with swelling, making it more pleasant for the patient. This result may have been attained because the fluid pressure exerted on the peripheral tissue was reduced. This was reflected in the feeling of reduced discomfort due to the relieved skin tension reported by the patients. This may have the added benefit of reducing reluctance to exercise. The beneficial effects of early activation of the patient as a way of preventing intensification of the symptoms of FS, post-hospital syndrome or rehospitalization should not be underestimated.

Limitations


Our research is not free from limitations, and this needs to be acknowledged. First, the study included a relatively small number of patients. This is due to the unique nature of our study population, which is comprised of elderly patients with many different chronic conditions. Due to the small study group, we decided not to include both genders to avoid heterogeneity within our sample, which could introduce another limitation. However, we felt that gender diversity was particularly important in the context of our study in terms of the effects of hormones on muscle tissue and, moreover, significant differences in muscle mass, strength and endurance. Another limitation is the lack of a control group. It is due to the fact that, at this stage of the research, we focused on the effects of exercise on hemodynamic parameters and muscle oxygenation, while the observed changes and their dynamics were compared to resting values. The methods used for diagnosis and assessment of pulmonary congestion have had limited accuracy and reliability. We endeavor to eliminate these limitations by continuing this research in the future.

Conclusions


We have demonstrated that assisted exercises of the lower limb are safe because they do not burden the circulatory system. This is because they did not cause changes in BP, HR and oxygen saturation or increase dyspnea; therefore, they can be performed during the initial rehabilitation period of male patients hospitalized for AHF. Furthermore, the presented data suggest that such physiotherapeutic interventions are beneficial, particularly in patients with peripheral congestion and lower limb edema, as they improve venous outflow and muscle oxygenation. Finally, assisted exercises helped reduce the severe and uncomfortable symptoms of AHF, such as feelings of tension and pain in the lower extremities, that limit the patient's mobility.


ORCID iDs

Olga Kisiel  <https://orcid.org/0000-0002-5398-5654>


Agnieszka Ewa Siennicka  <https://orcid.org/0000-0003-0988-5821>

Krystian Josiak  <https://orcid.org/0000-0003-2099-7453>

Robert Zymliński  <https://orcid.org/0000-0003-1483-7381>

Waldemar Banasiak  <https://orcid.org/0000-0003-0702-7508>

Kinga Węgrzynowska-Teodorczyk

 <https://orcid.org/0000-0001-9189-748X>

References

1. Ziaeian B, Fonarow GC. Epidemiology and aetiology of heart failure. *Nat Rev Cardiol*. 2016;13(6):368–378. doi:10.1038/nrcardio.2016.25
2. McDonagh TA, Metra M, Adamo M, et al. 2021 ESC guidelines for the diagnosis and treatment of acute and chronic heart failure. *Eur Heart J*. 2021;42(36):3599–3726. doi:10.1093/eurheartj/ehab368
3. Takara Y, Saitoh M, Morisawa T, et al. Clinical characteristics of older heart failure patients with hospital-acquired disability: A preliminary, single-center, observational study. *Cardiol Res*. 2021;12(5):293–301. doi:10.14740/cr1306
4. Reeves GR, Whellan DJ, Patel MJ, et al. Comparison of frequency of frailty and severely impaired physical function in patients ≥60 years hospitalized with acute decompensated heart failure versus chronic stable heart failure with reduced and preserved left ventricular ejection fraction. *Am J Cardiol*. 2016;117(12):1953–1958. doi:10.1016/j.amjcard.2016.03.046
5. Murad K, Kitzman DW. Frailty and multiple comorbidities in the elderly patient with heart failure: Implications for management. *Heart Fail Rev*. 2012;17(4–5):581–588. doi:10.1007/s10741-011-9258-y
6. Krumholz HM. Post-hospital syndrome: An acquired, transient condition of generalized risk. *N Engl J Med*. 2013;368(2):100–102. doi:10.1056/NEJMp1212324
7. Zisberg A, Shadmi E, Gur-Yaish N, Tonkikh O, Sinoff G. Hospital-associated functional decline: The role of hospitalization processes beyond individual risk factors. *J Am Geriatr Soc*. 2015;63(1):55–62. doi:10.1111/jgs.13193
8. Rossello X, Miró Ò, Llorens P, et al. Effect of Barthel index on the risk of thirty-day mortality in patients with acute heart failure attending the emergency department: A cohort study of nine thousand ninety-eight patients from the Epidemiology of Acute Heart Failure in Emergency Departments Registry. *Ann Emerg Med*. 2019;73(6):589–598. doi:10.1016/j.annemergmed.2018.12.009
9. Gill TM, Allore HG, Gahbauer EA, Murphy TE. Change in disability after hospitalization or restricted activity in older persons. *JAMA*. 2010;304(17):1919. doi:10.1001/jama.2010.1568
10. Martínez-Velilla N, Casas-Herrero A, Zambom-Ferraresi F, et al. Effect of exercise intervention on functional decline in very elderly patients during acute hospitalization: A randomized clinical trial. *JAMA Intern Med*. 2019;179(1):28. doi:10.1001/jamainternmed.2018.4869
11. de Morton N, Keating JL, Jeffs K. Exercise for acutely hospitalised older medical patients. *Cochrane Database Syst Rev*. 2007;2007(1):CD005955. doi:10.1002/14651858.CD005955.pub2

12. Yasmeen I, Krewulak KD, Grant C, Stelfox HT, Fiest KM. The effect of caregiver-mediated mobility interventions in hospitalized patients on patient, caregiver, and health system outcomes: A systematic review. *Arch Rehabil Res Clin Transl*. 2020;2(3):100053. doi:10.1016/j.arrct.2020.100053
13. Semsar-Kazerooni K, Dima D, Valiquette J, Berube-Dufour J, Goldfarb M. Early mobilization in people with acute cardiovascular disease. *Can J Cardiol*. 2021;37(2):232–240. doi:10.1016/j.cjca.2020.03.038
14. Kitzman DW, Whellan DJ, Duncan P, et al. Physical rehabilitation for older patients hospitalized for heart failure. *N Engl J Med*. 2021;385(3):203–216. doi:10.1056/NEJMoa2026141
15. Munir H, Morais JA, Goldfarb M. Health-related quality of life in older adults with acute cardiovascular disease undergoing early mobilization. *CJC Open*. 2021;3(7):888–895. doi:10.1016/j.cjco.2021.02.013
16. Kakutani N, Fukushima A, Kinugawa S, et al. Progressive mobilization program for patients with acute heart failure reduces hospital stay and improves clinical outcome. *Circ Rep*. 2019;1(3):123–130. doi:10.1253/circrep.CR-19-0004
17. Piepoli MF, Conraads V, Corrà U, et al. Exercise training in heart failure: From theory to practice. A consensus document of the Heart Failure Association and the European Association for Cardiovascular Prevention and Rehabilitation. *Eur J Heart Fail*. 2011;13(4):347–357. doi:10.1093/eurjhf/hfr017
18. Reeves GR, Whellan DJ, Duncan P, et al. Rehabilitation Therapy in Older Acute Heart Failure Patients (REHAB-HF) trial: Design and rationale. *Am Heart J*. 2017;185:130–139. doi:10.1016/j.ahj.2016.12.012
19. Pollock A, Baer G, Campbell P, et al. Physical rehabilitation approaches for the recovery of function and mobility following stroke. *Cochrane Database Syst Rev*. 2014;2014(4):CD001920. doi:10.1002/14651858.CD001920.pub3
20. Trafidło T, Gaszyński T. NIRS: Spektroskopia bliskiej podczerwieni jako wielofunkcyjna metoda monitorowania miejscowej oksygenacji tkankowej w anestezjologii i ratownictwie. *Anestezjologia i Ratownictwo*. 2009;3:351–359.
21. Barroco AC, Sperandio PA, Reis M, Almeida DR, Neder JA. A practical approach to assess leg muscle oxygenation during ramp-incremental cycle ergometry in heart failure. *Braz J Med Biol Res*. 2017;50(12):e6327. doi:10.1590/1414-431x20176327
22. Jones S, Chiesa ST, Chaturvedi N, Hughes AD. Recent developments in near-infrared spectroscopy (NIRS) for the assessment of local skeletal muscle microvascular function and capacity to utilise oxygen. *Artery Res*. 2016;16:25–33. doi:10.1016/j.artres.2016.09.001
23. De Blasi RA, Palmisani S, Alampi D, et al. Microvascular dysfunction and skeletal muscle oxygenation assessed by phase-modulation near-infrared spectroscopy in patients with septic shock. *Intensive Care Med*. 2005;31(12):1661–1668. doi:10.1007/s00134-005-2822-y
24. Hiki M, Iwata H, Takasu K, et al. Elevated heart rate in combination with elevated blood pressure predicts lower cardiovascular mortality in acute decompensated heart failure. *Int Heart J*. 2020;61(2):308–315. doi:10.1536/ihj.19-521
25. Aalders M, Kok W. Comparison of hemodynamic factors predicting prognosis in heart failure: A systematic review. *J Clin Med*. 2019;8(10):1757. doi:10.3390/jcm8101757
26. Carlier PG, Bertoldi D, Baligand C, Wary C, Fromes Y. Muscle blood flow and oxygenation measured by NMR imaging and spectroscopy. *NMR Biomed*. 2006;19(7):954–967. doi:10.1002/nbm.1081
27. Barroco AC, Sperandio PA, Reis M, Almeida DR, Neder JA. A practical approach to assess leg muscle oxygenation during ramp-incremental cycle ergometry in heart failure. *Braz J Med Biol Res*. 2017;50(12):e6327. doi:10.1590/1414-431x20176327
28. Kravari M, Vasileiadis I, Gerovasili V, et al. Effects of a 3-month rehabilitation program on muscle oxygenation in congestive heart failure patients as assessed by NIRS. *Int J Ind Ergon*. 2010;40(2):212–217. doi:10.1016/j.ergon.2009.03.006
29. La Monaca M, David A, Gaeta R, Lentini S. Near-infrared spectroscopy for cerebral monitoring during cardiovascular surgery [in Italian]. *Clin Ter*. 2010;161(6):549–553. PMID:21181086.
30. Belardinelli R, Georgiou D, Barstow TJ. Near infrared spectroscopy and changes in skeletal muscle oxygenation during incremental exercise in chronic heart failure: A comparison with healthy subjects. *G Ital Cardiol*. 1995;25(6):715–724. PMID:7649420.
31. Belardinelli R. Monitoring skeletal muscle oxygenation during exercise by near infrared spectroscopy in chronic heart failure. *Congest Heart Fail*. 1999;5(3):116–119. PMID:12189315.
32. Pang CCY. Measurement of body venous tone. *J Pharmacol Toxicol Methods*. 2000;44(2):341–360. doi:10.1016/S1056-8719(00)00124-6
33. Scott AC, Wensel R, Davos CH, et al. Chemical mediators of the muscle ergoreflex in chronic heart failure: A putative role for prostaglandins in reflex ventilatory control. *Circulation*. 2002;106(2):214–220. doi:10.1161/01.CIR.0000021603.36744.5E
34. Kaczmarek A, Banasiak W, Ponikowski P. The role of skeletal muscle ergoreceptors in chronic heart failure [in Polish]. *Kardiologia Pol*. 2004;60(4):374–376. PMID:15226790.
35. Middlekauff HR. Making the case for skeletal myopathy as the major limitation of exercise capacity in heart failure. *Circ Heart Failure*. 2010;3(4):537–546. doi:10.1161/CIRCHEARTFAILURE.109.903773
36. Coats AJS. What causes the symptoms of heart failure? *Heart*. 2001;86(5):574–578. doi:10.1136/heart.86.5.574
37. Piepoli MF, Coats AJS. The 'skeletal muscle hypothesis in heart failure' revised. *Eur Heart J*. 2013;34(7):486–488. doi:10.1093/eurheartj/ehs463
38. Mentz RJ, Whellan DJ, Reeves GR, et al. Rehabilitation intervention in older patients with acute heart failure with preserved versus reduced ejection fraction. *JACC Heart Fail*. 2021;9(10):747–757. doi:10.1016/j.jchf.2021.05.007
39. Ponikowski P, Voors AA, Anker SD, et al. 2016 ESC guidelines for the diagnosis and treatment of acute and chronic heart failure. *Kardiologia Pol*. 2016;74(10):1037–1147. doi:10.5603/KP.2016.0141
40. Rehabilitacja pacjentów z niewydolnością serca. In: *Rekomendacje w zakresie realizacji kompleksowej rehabilitacji kardiologicznej – Stanowisko Ekspertów Sekcji Rehabilitacji Kardiologicznej i Fizjologii Wyższej Polskiego Towarzystwa Kardiologicznego*. Gdańsk, Poland: Wydawnictwo Asteria Med;65–72. <https://kif.info.pl/file/2018/07/Rekomendacje-w-zakresie-realizacji-kompleksowej-rehabilitacji-kardiologicznej-1.pdf>.
41. Hodgson CL, Stiller K, Needham DM, et al. Expert consensus and recommendations on safety criteria for active mobilization of mechanically ventilated critically ill adults. *Crit Care*. 2014;18(6):e58. doi:10.1186/s13054-014-0658-y
42. Connolly B, Salisbury L, O'Neill B, et al. Exercise rehabilitation following intensive care unit discharge for recovery from critical illness. *Cochrane Database Syst Rev*. 2015;2015(6):CD008632. doi:10.1002/14651858.CD008632.pub2
43. Goldfarb M, Afalalo J, Chan A, Herscovici R, Cercek B. Early mobility in frail and non-frail older adults admitted to the cardiovascular intensive care unit. *J Crit Care*. 2018;47:9–14. doi:10.1016/j.jccr.2018.05.013
44. Węgrzynowska-Teodorczyk K, Siennicka A, Josiak K, et al. Evaluation of skeletal muscle function and effects of early rehabilitation during acute heart failure: Rationale and study design. *BioMed Res Int*. 2018;2018:1–8. doi:10.1155/2018/6982897
45. Flint KM, Forman DE. Lessons from the first 202 REHAB-HF participants: Will adherence be the Achilles' heel of exercise rehabilitation among older adults hospitalized for heart failure? *Circ Heart Fail*. 2018;11(11):e005611. doi:10.1161/CIRCHEARTFAILURE.118.005611
46. Reeves GR, Whellan DJ, O'Connor CM, et al. A novel rehabilitation intervention for older patients with acute decompensated heart failure. *JACC Heart Fail*. 2017;5(5):359–366. doi:10.1016/j.jchf.2016.12.019
47. Martin-Du Pan RC, Benoit R, Girardier L. The role of body position and gravity in the symptoms and treatment of various medical diseases. *Swiss Med Wkly*. 2004;134(37–38):543–551. doi:2004/37/smw-09765
48. Mehra MR, Stewart GC, Uber PA. The vexing problem of thrombosis in long-term mechanical circulatory support. *J Heart Lung Transplant*. 2014;33(1):1–11. doi:10.1016/j.healun.2013.12.002
49. Allen LA, Tang F, Jones P, Breeding T, Ponirakis A, Turner SJ. Signs, symptoms, and treatment patterns across serial ambulatory cardiology visits in patients with heart failure: Insights from the NCDR PINNACLE® registry. *BMC Cardiovasc Disord*. 2018;18(1):80. doi:10.1186/s12872-018-0808-2
50. Dahn R, Walker S. New medications in the treatment of acute decompensated heart failure. *Hosp Pharm*. 2018;53(2):85–87. doi:10.1177/001857817750096