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Ngoné Diaba Gaye *
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Effects of exercise-based cardiac rehabilitation on left ventricular systolic and diastolic function in sub-Saharan African Patients

Ngoné Diaba Gaye [1]*, Aliou Alassane Ngaidé [2,3,4], Joseph Mingou [2,4], Fatou Aw [4], Mame Madjiguène Ka [5], Aimé Mbaye Sy [2], Seydina Issa Kane [3], Abdoul Kane [2,3]

[1]Department of cardiac rehabilitation, Ibra Mamadou Wane Medical Center, Dakar, Senegal

[2]Department of cardiology, Dalal Jam Hospital, Guediawaye, Dakar, Senegal.

[3]Department of cardiology, Idrissa Pouye General Hospital, Dakar, Senegal.

[4]School of Medicine, Cheikh Anta Diop University, Dakar, Senegal.

***Corresponding Author:** Ngone Diaba Gaye, Department of cardiac rehabilitation, Ibra Mamadou Wane Medical center

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Abstract

Background: Cardiac rehabilitation (CR) represents a highly efficacious non-pharmacological intervention for cardiac patients. Yet, its effect on left ventricular systolic function remains controversial and there is a lack of data in sub-Saharan African patients. The aim of this study was to assess effects of exercise based cardiac rehabilitation on left ventricular systolic and diastolic function after cardiac rehabilitation in a black African population.

Results: A total of 103 patients with a male-to-female ratio of 1.64. The mean age was 56,37 yo ± 11,59. Most of the patients (83.5%) presented with dyspnea stage 2 to 3 of classification. Sedentary lifestyle and dyslipidemia were the predominant cardiovascular risk factors, in 90% and 76% of cases respectively. Coronary artery disease was the primary indication, accounting for 74.8% of cases. After cardiac rehabilitation improvement in both left ventricular ejection fraction [+ 17%, P 0.000] and stroke volume [+ 13.5 ml, P 0.00]. This improvement was particularly significant among patients with a left ventricular ejection fraction (LVEF) < 40%. Mean E/e' ratio decreased significantly upon completion of cardiac rehabilitation [-2.91 pts, P 0.000]. Furthermore, 37.9% of patients had elevated left ventricular filling before CR against 5.9 % after CR (P 0.000).

Conclusion: Cardiac rehabilitation results in significant improvement in both systolic and diastolic left ventricular function in our population subset.

Keywords: cardiac rehabilitation; sub-saharan Africa; left ventricular systolic function; left ventricular diastolic function; coronary artery disease; chronic heart failure

Abbreviations

6MWTD 6 minutes walk test distance

ASE American Society of Echocardiography

CAD Coronary Artery Disease

CR Cardiac Rehabilitation

CVDs Cardiovascular diseases

DALY Disability-adjusted life year

HR Heart Rate

IVSd Interventricular Septum Thickness

LAA Left Atrial Area

LV Left Ventricle

LVEDd Left Ventricle End-Diastolic Diameter

LVEF Left Ventricular Ejection Fraction

NCDs non-communicable diseases

NYHA New York Heart Association

PASP Pulmonary Arterial Systolic Pressure

PWT Posterior Wall Thickness

RAA Right Atrial Area

RV Right Ventricule

RVEDd Right Ventricular End-Diastolic Diameter

SAT Systolic Annular Tissue Velocity

TAPSE Tricuspid Annular Plane Systolic Excursion

THR Training Heart Rate

Background

Cardiovascular diseases (CVDs) are one of the leading causes of non-communicable disease (NCDs) deaths globally and in sub-Saharan Africa[1]. The burden of NCDs, including CVDs, has been on the rise in the region over the past two decades due to various risk factors like unhealthy diets, physical inactivity, hypertension, and obesity[1,2]. Ischemic heart disease is the leading cause of cardiovascular disease burden among males in Sub-Saharan Africa, resulting in 4,857,246.3 DALYs in 2017[2]. Cardiovascular disease burden, driven by increasing risk factors such as smoking and unhealthy diets, is likely to increase and pose challenges to health systems in Sub-Saharan Africa[3–6]. Limited access to healthcare services, delayed presentation, and inadequate management contribute to the high morbidity and mortality associated with CVDs in sub-Saharan Africa. Addressing the CVDs burden in this region requires a multifaceted approach, including strengthening primary and secondary prevention strategies, improving access to diagnosis and treatment, and implementing effective rehabilitation programs tailored to the local context. Cardiac rehabilitation is a multidisciplinary intervention that has been shown to improve clinical outcomes and quality of life in patients with various cardiovascular conditions, including heart failure[7–10]. Despite its proven efficacy, cardiac rehabilitation programs have been relatively delayed in our region, particularly in Senegal. Improving access to evidence-based interventions, such as cardiac rehabilitation, is crucial to mitigating the growing burden of CVDs in the region[11,12]. One of the primary objectives of cardiac rehabilitation is to enhance functional abilities, as measured by the amount of energy expended when carrying out different physical tasks. This goal is associated with recognizing that physical capacity is now acknowledged as the most influential independent predictor of longevity[13]. Overall, studies show significant improvement in physical capacity and diastolic function indices after participation in a cardiac rehabilitation program[14–16]. Yet, the effects of exercise-based cardiac rehabilitation on left ventricular systolic function remain truly controversial[17–23]. Furthermore, there is little to no evidence in the black African population. Therefore, we aimed to evaluate the effects of CR on left ventricular systolic and diastolic function in a sub-Saharan African population. A secondary objective was to assess the improvement of right ventricular systolic function after completion of CR program.

Methods

Study Design and Period

This study employed a descriptive and analytical cross-sectional design, incorporating both retrospective and prospective data collection methods. Data collection took place between February 1, 2021, and June 30, 2023, at the cardiovascular rehabilitation department of Idrissa POUYE General Hospital.

The study cohort consisted of patients aged 18 years and older, referred to the cardiovascular rehabilitation department of Idrissa Pouye general hospital of Dakar. We included all patients who had undergone at least 10 sessions of exercise training and have had an echocardiogram both before and after cardiac rehabilitation.

Excluded from our study were:

•All patients who expressed a refusal to participate.

•All patients who were irregularly monitored, meaning those who missed at least 3 consecutive training sessions.

•All patients who refused consent after receiving appropriate and thorough information.

•All patients whose initial records were either unavailable or incomplete.

Data Collection

All patients referred for cardiac rehabilitation underwent a comprehensive initial evaluation, which included: a thorough medical history, clinical examination, laboratory tests, assessment of cardiovascular risk factors, electrocardiogram, transthoracic echocardiography, exercise stress testing, and a 6-minute walk test. This initial evaluation allowed for risk stratification of the patient and adaptation of the modalities and monitoring of cardiac rehabilitation.

All echocardiographic examinations were performed using Vivid 8 echocardiography machines from GE Healthcare, equipped with an adult cardiac probe ranging from 2 to 5 MHz. The operator was a cardiologist with at least 4 years of experience in echocardiography.

Exercise stress testing was conducted on a treadmill or a GE Healthcare cycle ergometer, following the modified BRUCE protocol or the protocol for elderly subjects with significant physical deconditioning. The exercise tests determined the level of retraining, initial workload, resting heart rate (HR), maximal exercise heart rate (HR max), and calculated the training heart rate (THR) using the Karvonen formula[24].

THR = Resting HR + K (HR max - Resting HR).

K = 0.6 if the patient is not on beta-blockers, K = 0.8 if the patient is on beta-blockers.

The training protocol involved three sessions per week, each session comprising endurance training lasting 30 to 45 minutes, preceded by a warm-up phase of 3 to 5 minutes and followed by a 3 to 5-minute recovery phase. Additionally, patients engaged in 30 to 45 minutes of gymnastics.

During their stay in the cardiovascular rehabilitation unit, all patients were offered participation in an educational program (group sessions, sometimes individual) regarding their disease and treatment, dietary counseling aimed at lifestyle modifications to control cardiovascular risk factors, physical activity guidance, assistance with smoking cessation, and support for potential return to work.

At the end of the program, post-rehabilitation exercise stress testing, the 6-minute walk test, and echocardiography were performed.

Study Parameters

- Socio-demographic parameters: age, sex, place of residence, healthcare insurance coverage, profession.
- History of high blood pressure, diabetes mellitus or tobacco use
- Physical examination: general condition, dyspnea according to NYHA, blood pressure, heart rate, body mass index (BMI) and waist circumference.
- Patient's medication and compliance according to Girerd questionnaire[25]
- LDLc levels before and after CR
- 6 minutes walk test distance (6MWTD) covered before and after CR
- Exercise testing[26] : percentage of theoretical maximum heart rate achieved, number of METs, blood pressure response to exercise, heart rate adaptation during exercise (considered good if peak heart rate minus resting heart rate exceeded 50 bpm), adequacy of heart rate recovery adaptation (considered good if the difference between maximum heart rate during exercise and heart rate after one minute of recovery was greater than 12 bpm)[26], and the presence or absence of arrhythmias during exercise.
- Echocardiography: The following parameters were collected, with normal values defined according to the American Society of Echocardiography (ASE) guidelines[27,28].
  - Chamber quantification: left ventricle end-diastolic diameter (LVEDd), interventricular septum thickness (IVSd), posterior wall thickness (PWT), left atrial area (LAA), right atrial area (RAA); right ventricular end-diastolic diameter (RVEDd);
  - Biventricular systolic function: Left ventricular ejection fraction (LVEF) using Simpson's biplane method, stroke volume, right ventricle S' (RV S'), TAPSE
  - Left diastolic function: mean E/e' ratio, pulmonary arterial systolic pressure (PASP)

Statistical Analysis

Data analysis was performed using SPSS (Statistical Package for Social Sciences) version 24.0. In the case of quantitative observations, baseline characteristics were presented as mean standard deviation (SD) for parameters with normal distribution. Median interquartile range was used for parameters showing no normal distribution. Pearson's Chi-square test or Fisher's bilateral exact test were employed to compare frequencies upon applicability. Mean comparisons were executed using the analysis of variance test, with a significance threshold set at $p < 0.05$, with odds ratios calculated for significant associations. The 95% confidence intervals of the odds ratios were determined using the Woolf method.

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Results

A total of 103 patients predominantly males (62.2%) were included in the present study. The mean age was 56,37±11,59 years old. 83.5% of the patients presented with dyspnea stage 2 to 3 of NYHA classification. Sedentary lifestyle and dyslipidemia were the predominant cardiovascular risk factors, in 90% and 76% of cases respectively. Coronary artery disease (CAD) was the primary indication, accounting for 74.8% of cases. Demographic characteristics of our population at baseline are summarized in **table 1**. Overall, CR had a positive impact on weight, waist circumference and LDLc reduction **(Table 2).** The mean pre-CR LVEDd was 51.9 mm ± 8.1 compared to 50.3 mm ± 4.5 after CR, a significant decrease of -1.57 mm (P 0.043). Greater decrease in LVEDd was found in male subjects (P 0.049), non-sedentary subjects (P 0.043), patients with dilated cardiomyopathy (P 0.00) and those who had more than 15 training sessions (P 0.04).

Parameters	Pre CR	Post CR	p value
Systolic BP (mm Hg)	131.5	129.3	0.17
Diastolic BP (mm Hg)	79.9	72.2	0.000
Weight (kg)	78.6 ± 11.4	74.2 ± 11.6	0.002
BMI	24.7 ± 3.5	23,4 ± 2.54	0.002
AC (cm)	90.8 ± 19.1	86.9 cm ± 12.5	0.001
Resting HR (bpm)	81.8 ± 11.2	68.4 ± 7.9	0.000
LDLc (g/l)	1.71 ± 0,63	0.99 ± 0,4	0.000
LVEF (%)	43.1 ± 10.8	51.9 ± 11	0.000
METS	4.3 ± 2.1	6.78 ± 2.8	0.000
6MWTD	337.82 ±113	522.7 ± 118.99	0.000

Table 1: Patient's demographics at baseline

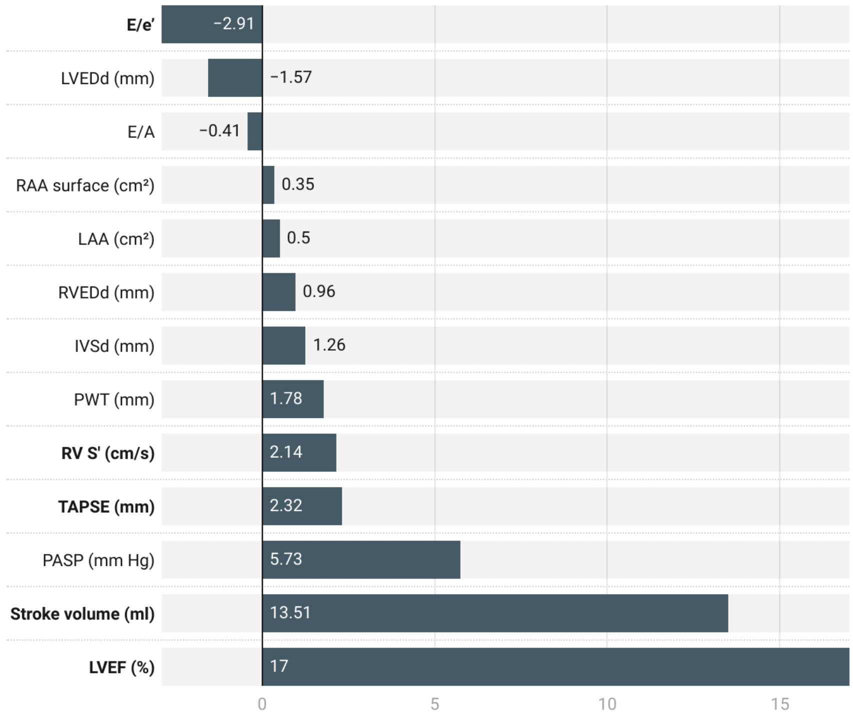
Parameters	Value
Age (yrs, mean value ± SD)	56.4 ± 11.6
Male (%)	62.1
Low litteracy (%)	33.0
Employment (%)	20.7
Lack of health insurance (%)	71.9
Living in remote areas (%)	16.5
Number of sessions completed (Mean value ± SD)	17.6 ± 2.8
Dyslipidemia (%)	73.8
Hypertension (%)	47.6
Diabetes mellitus (%)	43.7
Tobacco use (%)	30.1
Obesity (%)	8.7
BMI (kg/m², mean value ± SD)	24.7 ± 3.4
Left ventricular ejection fraction<40% (%)	45.1
Coronary artery disease (%)	74.8
Peripheral artery disease (%)	4.9
Dilated cardiomyopathy (%)	15.5
Valvular heart disease (%)	1.9
Hypertensive cardiomyopathy (%)	1.0
Restrictive cardiomyopathy (%)	1.0
Peripartum cardiomyopthy (%)	1.0

Table 2: Evolution of clinical and biological parameters

Moreover, cardiac rehabilitation yields a significant increase in stroke ejection volume. Likewise, left ventricular systolic function also improved following cardiovascular rehabilitation, with the mean LVEF increasing from 43.8% ± 10.88 before cardiac rehabilitation to 51.90% ± 11.03, demonstrating a significant gain of 17% (P 0.00). This improvement in LVEF was more significant among patients with dilated cardiomyopathy [+10.6 pts, p=0.003], in age < 50 years [+10.9 pts, P<0.001] and women [+9.4 pts, P 0.003].

Similarly, the assessment of diastolic function before and after cardiac rehabilitation revealed significant improvement in the diastolic function of the left ventricle. Prior to cardiac rehabilitation, 37.9% of patients exhibited elevated filling pressures, compared to 5.9% after cardiac rehabilitation. Furthermore, the mean E/e' ratio demonstrated a remarkable decrease after cardiac rehabilitation, with a significant reduction of 2.91 (P 0.00).

Right ventricular systolic function also demonstrated significant improvement in post-cardiac rehabilitation. There was a notable increase in tricuspid annular plane systolic excursion (TAPSE) from an average of 18.1 ± 3.3 mm before rehabilitation to 20.4 ± 3.7 mm after cardiac rehabilitation (P 0.00). Similarly, the systolic annular tissue velocity (SAT) increased from 11.9 (±2.2 cm/s) before cardiac rehabilitation to 13.4 ± 2.3 cm/s after cardiac rehabilitation (P 0.00).



IVSd = interventricular septum thickness, LAA = left atrial area; LVEDd = left ventricular end-diastolic diameter in diastole; LVEF = left PASP = pulmonary arterial systolic pressure; PWT = posterior wall thickness; RAA= Right atrial area; RV S' = Right ventricle S'; RVEDd = right ventricular end-diastolic diameter;

Figure 1 sums up mean variations in echocardiographic parameters pre and post-CR.

Discussion

In this Senegalese cohort of 103 patients with CAD being the most frequent indication, cardiac rehabilitation program improved significantly left ventricular systolic and diastolic function. Furthermore, post-CR peak exercise capacity was improved in our patients. Additionally, LVEDd was significantly decreased after CR in our study, showing that exercise had no adverse effects on cardiac remodeling in our patients.

The improvement of LVEF and stroke volume after CR found in the present study is consistent with recent literature[16,17,29,30]. Sadhegi and al. found a significant increase in LVEF in Iranian patients after CR (45.14 % ± 5.77 versus 50.44% ± 8.70; P <0.001) [30]. This could be attributed to reduction in peripheral resistance, improvement in endothelial function, modification of inflammatory markers, coagulation, and clotting factors, and development of coronary collateral vessels after regular exercise[31,32]. Also, CR is a comprehensive multidisciplinary program that includes drug optimization, dietary counselling, risk factors control and smoking cessation. These components may also play a part on improvement of left ventricular systolic function after CR.

E/e' ratio, a left diastolic function indice, was also improved by CR in our patients. This finding has been also reported in previous studies, especially in heart failure patients [33,34]. E/e' ratio is considered to be more sensitive and accurate than the E/A ratio for the measurement of ventricular relaxation and diastolic dysfunction. However, it is important to note that diastolic function should not be evaluated on one single diastolic index. We did not report changes in diastolic dysfunction grading or left atrial volume index (LAVI), which may limit the extent of our findings.

We found that the right ventricular systolic function was also substantially improved after CR. Prognostic value of the RV function in coronary artery disease, particularly following reduction in exercise tolerance is well established [35]. Indeed, increased risk of death, arrhythmia, and shock has been demonstrated in patients with RV myocardial dysfunction[35]. Baker et al.[36] and Di Salvo [37] found a strong link between RV function and exercise capacity and suggested that exercise capacity could be the primary indicator of mortality. They also noted that exercise capacity seemed to have a stronger connection to RV function than LV function. These results emphasize the complex nature of changes in RV function during exercise regimens, particularly in cardiac rehabilitation programs.

The present study took place in Senegal a sub-Saharan African country, giving valuable insights on an understudied population in CR field. However, our study has some limitations. We are unable to gauge the precise impact of CR on our patients compared to standard medical treatment due to the absence of a control group. Additionally, the lack of follow-up hinders our ability to assess the long-term outcomes of CR in our patients. Thus, it is essential to conduct controlled studies with follow-ups in the Senegalese population to ascertain the specific impact of the CR program on ventricular function in our patients.

Conclusion

The present study demonstrates that exercise-based cardiac rehabilitation leads to significant improvements in both systolic and diastolic left ventricular function in a Sub-Saharan African population. Despite its limitations, these findings underscore the importance of cardiac rehabilitation as a valuable intervention for improving outcomes of CVD's patients in SSA. Further research with larger sample sizes and longer follow-up periods is necessary to confirm our findings and investigate the long-term impact of cardiac rehabilitation on clinical outcomes in this population.

Declarations

Ethics approval and consent to participate Written informed consent for participation was obtained from the patients following a thorough explanation of the study

Consent for publication

Not applicable

Data availability

The data that support the findings of this study are available from Pr Aliou Alassane Ngaide but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of Pr Aliou Alassane Ngaide.

Competing interests

The authors declare that they have no competing interests

Funding

The study had no sponsorship.

Author contributions

NDG and AAN are expected to have made substantial contributions to the conception and design of the work; SIK are expected to have made substantial contributions to the acquisition and analysis, SIK, AAN and NDG are expected to have made substantial contributions to the interpretation of data; NDG have drafted the work and substantively revised it. All authors read and approved the final manuscript.

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