Original Article

Heart Rate Recovery after a 6-minute Walk test in Patients with Lower Extremity Artery Disease in Burkina Faso, sub-Saharan Africa

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Abstract

Background: Heart rate recovery (HRR) is a measure of fitness and an indication of cardiac health. The decrease in heart rate occurring immediately after exercise is caused by increased vagal activity and sympathetic withdrawal occurring after exercise.

Objective: Our aim was to study the relationship between of the clinical severity of the lower limb artery disease (Fontaine classification) assessed during a 6-minute walking test and the decrease in heart rate (HR) from maximal exercise HR at 1-minute post-exercise (HRR1).

Material and method: We studied patients were enrolled from January to December 2021 and screened in the vascular function exploration unit of the Souro SANOU University Hospitalof Bobo-Dioulasso, Burkina Faso, sub-Saharan Africa.

Results: A total of 98 patients were included with a mean age of 53.6 ± 11.2 years, predominantly female (60.2%). The mean values were:0.834 ± 0.16 for ABI, 77± 11 bpm for resting HR, 108 ± 14bpm for end-exercise HR, 15bpm ± 8bpm for HRR1, 296± 95 m for maximum walking distance. Among the groups of the Fontaine classification, group IV walked the least (224±115m) and had the smallest HRR1 (11±8 bpm).

Conclusion: Our study showed a significant relationship between HRR1 after a 6-minute walk test and the severity of lower limb ischemia. This could potentially lead to better peripheral arterial disease management strategies based on post-exercise cardiac recovery.

Keywords: *Heart rate, 6-minute walk test, heart rate recovery, ischemia*

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Introduction

Muscular exercise increases oxygen consumption and carbon dioxide production[1]. One of the functions of the circulatory system is to allow increased oxygen delivery and carbon dioxide removal, via cardiac output, which is the product of heart rate (HR) and systolic ejection volume. Increasing cardiac output by raising HR is therefore a means of meeting oxygen demand during exercise.

Heart rate recovery at one minute from the end of exercise (HRR1) is a measure of physical fitness and an indication of heart health[2,3]. The decrease in heart rate occurring immediately after exercise, is caused by the increase in vagal activity and sympathetic withdrawal occurring after exercise and is a powerful predictor of cardiovascular events and mortality [2,3]. A number of conditions can reduce the rate at which HR decrease after exercise leading to decreased HRR1 values. Indeed, a reduction in HRR1 is associated with carotid atherosclerosis[4] and myocardial ischemia[5]. Recent studies have also shown that HRR1 decreases with lower limb ischemia[6]. Abnormal HR decrement during recovery has been shown to be predictive of major cardiovascular events and all-cause mortality in both healthy and ill individuals[7,8,9,10].

While many data exist in western countries on HRR1, in Sub-Saharan Africa, littledata exist and have focused only on coronary artery disease[11].

In our context of limited resources in Burkina Faso, where the incidence of obliterative arteriopathy of the lower limbs is constantly increasing[12], no data have reported on the relationship between HRR1 and ischemia of the lower limbs.

The aim of this study was to study the relationship between HRR1 and the clinical severity of the lower limb artery disease after a 6-minute walk test in patients referred to the vascular functional exploration unit in Bobo-Dioulasso.

Materials and methods

Type of study and study population

A monocentric, descriptive and cross-sectional study was conducted from January to December 2021 in patients referred for arterial Doppler ultrasound of the lower limbs to the vascular functional exploration unit of the the Souro SANOU University Hospital of Bobo-Dioulasso, Burkina Faso.

Inclusion criteria

Patients with obliterative arteriopathy of the lower limbs confirmed by Doppler ultrasound and with no contraindication to the 6-minute walk test were included in the study.

Exclusion criteria

Patients with functional signs of osteoarticular disease, atrial fibrillation, unstable angina, myocardial infarction and those taking beta-blockers were excluded from the study.

Determination of sample size

For estimation of the sample size, we considered an alpha error risk of 5%. The formula used was: $n = [Z\alpha^2 p\,(1-p)]\,/e^2$.

where:

- n: sample size,
- $Z\alpha$: normal standard deviation for an alpha risk of 5% = 1.96,
- e: desired precision of 5%,
- p: prevalence.

$n = 3.8416 \times 0.25 \times 0.75\ /\ 0.0025 = 288$

Based on an estimated prevalence of 25% for lower limb artery disease among patients, the minimum sample size calculated using this formula was 288 patients. Assuming a non-response rate of 10%, the final sample size was determined to be 259patients. Ninety-eight (98) patients were finally included in this study.

Study protocol and parameters studied

A handheld Doppler probe (Dopplex D900, Huntleigh Healthcare Ltd, Cardiff.UK) and a manometer (Lian Scenic Spengler) were used to measure systolic blood pressures in the right brachial, dorsalis pedis, and posterior tibial arteries and left dorsalis pedis, posterior tibial, and brachial arteries. The ankle brachial index (ABI) was calculated by dividing average pressure in leg by the average brachial pressure[13]. Lower extremity artery disease (LEAD) was defined for an ABI < 0.9[13].

Doppler ultrasound was performed to assess arterial structure and hemodynamics using a Siemens® Acuson NX2 Doppler ultrasound scanner.

Patients with no contraindications and who gave oral and written consent to participate in the study were then offered a 6-minute walk test. The six-minute walk was measured at baseline and follow-up using a standardized protocol[14]. Participants received standardized instructions prior to the test, which included that the goal of the test was to cover as much ground as possible during the six minutes. The 6-minute walk test consisted in assessing the distance walked on flat ground over a 6-minute period, using a stopwatch and markers placed every 3 meters in a 30-meters corridorin the hospital. The distance completed after 6 minutes was recorded corresponding to the maximum walking distance (MWD) in 6 minutes.

Heart rate was measured at rest before the 6-minute walk test, when the walk was stopped and 1 minute after the walk test, using an Apple Watch Series 4 heart rate monitor fitted to the patients' wrists.

Heart rate increase with exercise(Delta HR) was calculated as the difference between heart rate at the end of exercise and heart rate at rest.

The heart rate at 1-minute post-exercise was subtracted from the end-of-exercise HR to calculate HRR1.

After the 6-minute walk test, we classified patients into 4 groups according to the clinical severity of their LEAD using the Fontaine's classification[15].

Demographics and clinical data were collected (age, sex, body mass index (BMI), cardiovascular risk factors).

Statistical analysis

The analysis consisted in producing descriptive statistics for the study population. Quantitative data were expressed as means and standard deviations. Qualitative data were expressed as absolute frequencies and percentages. The statistical test used for comparison was the chi-square test. Patients were classified into four groups according to Fontaine's classification. The fourth group represented the most severe ischemia. We tested the interaction between the Fontaine severity and variables such as ABI, different heart rate variations and maximum walking distance. Statistical analyses were performed using Epi info software version 7.2. and SAS 9.2(32). The level of statistical significance was set at 0.05.

Ethical considerations

This study was approved by the ethics committee of the Souro SANOU University Hospital of Bobo-Dioulasso on December, 28, 2020 with the authorization number 2020-588/MS/SG/CHUSS/DG. Data was collected and analyzed anonymously and confidentially with the informed and written consent of the participating patients.

Results

Sociodemographic characteristics

During the study period, lower extremity artery disease was diagnosed in 185 patients. Of a total of 122 patients who met the inclusion criteria and agreed to take part in the study, we included a total of 98 patients who had completed the 6-minute walk test. Females'patients were predominant and accounted for 60.2% (n=59).

The average age of our patients was 53.6 ± 11.2 years.

Clinical data

The mean body mass index (BMI) was 26.82 ± 5.36 Kg/m^2.

The main cardiovascular risk factors found are shown in following table (Table 1).

Table 1: Distribution of patients according to cardiovascular risk factors

Cardiovascular risk factors	Frequency	Proportion %
Sedentary lifestyle	61	62.2
Overweight - obesity	57	58.2
Diabetes	51	52.0
Hypertension	63	64.3
Hypercholesterolemia	11	11.2
Smoking	8	08.2

The mean values of the patient's parameters are given in Table 2.

Table 2: Mean parameter values of the various patient's

Parameter	Mean values
ABI	0.83 ± 0.16
Resting HR	77 ± 11 bpm
End-of-exercise HR	108 ± 14 bpm
Δ HR	31± 9 bpm
HRR1	15 ± 8bpm
MWD	296± 95 m

***ABI**: the ankle-brachial index is the ratio of the systolic blood pressure measured at the ankle to that measured at the brachial artery. **Resting HR**: the heart rate measured at rest before the 6-minute walk test. **Bpm** heart rate in beats per minute. **End-exercise HR:** the heart rate at the end of the 6-minute walk test.**Δ HR** : the heart rate increase with exercise (Delta HR), calculated as the difference between heart rate at the end of exercise and heart rate at rest. **HRR1**: the heart rate at 1-minute post-exercise was subtracted from the end-of-exercise HR. **MWD**: the maximum walking distance completed after the 6-minute walk test in meters (**m**)*

We categorized patients into 4 groups according to the Fontaine's classification (Table 3).

Table 3: Distribution of patients by groups of arterial disease by Fontaine's classification

GROUP	Frequency	Proportion %
I : Asymptomatic atheromatic lesions	15	15.3
II:Stress ischemia, weak intermittent claudication	19	19.4
III:Decubitus pain, stress ischemia, weak intermittent claudication	26	26.5
IV:Trophic disorders, ulcers	38	38.8

Group I had an HRR1 of 20 ± 10 bpm and a maximum walking distance (MWD) of 443±59m, Group II had an HRR1 of 19 ± 8 bpm and a walking distance of 333.5±87m, Group III had an HRR1 of 16 ± 8 bpm and a walking distance of 292±85 m and Group IV had an HRR1 of 11 ± 8 bpm and a walking distance of 224±115 meters, with a statistically significant difference (p<0.05) (Table 4).

Table 4: Distribution of the groups of patients by stage of arterial disease

	Group I	Group II	Group III	Group IV	
n	**15**	**19**	**26**	**38**	**p**
Female sex (n)	9	11	14	25	0.251
ABI	0.85±0.12	0.85± 0.16	0.83± 0.18	0.82± 0.16	<0.05
Resting HR (bpm)	72 ± 8	73 ± 10	76 ± 10	81± 12	<0.05
End-exercise HR (bpm)	107± 11	106 ± 18	108± 17	110 ± 12	<0.05
Δ HR(bpm)	35 ± 12	32 ± 11	32 ± 8	29 ± 8	<0.05
HRR1 (bpm)	20 ± 10	19 ± 8	16 ± 8	11 ± 8	<0.05
MWD (m)	443±59	333.5±87	292±85	224±115	<0.05

***ABI**: the ankle-brachial index is the ratio of the systolic blood pressure measured at the ankle to that measured at the brachial artery. **Resting HR**: the heart rate measured at rest before the 6-minute walk test. **Bpm** heart rate in beats per minute. **End-exercise HR:** the heart rate at the end of the 6-minute walk test. **Δ HR** : the heart rate increase with exercise (Delta HR), calculated as the difference between heart rate at the end of exercise and heart rate at rest. **HRR1**: the heart rate at 1-minute post-exercise was subtracted from the end-of-exercise HR. **MWD**: the maximum walking distance completed after the 6-minute walk test in meters (**m**)*

Discussion

This study aimed to evaluate the relationship between HRR at 1 minute recovery after a 6-minute walk test in patients and the clinical severity of LEAD in patients referred to the vascular functional exploration unit in Bobo-Dioulasso. This study is the first of its kind in our geographical context.

Regarding the socio-demographic characteristics, 60.2% (n=59) of the patients were female. Although this result was found by Semporé et al.[12], it differs from most studies on lower limb artery disease, which is generally slightly higher in men than in women [6,15]. This could be related to the predisposition of female gender to cardiovascular risk factors (diabetes, overweight/obesity, hypercholesterolemia) at the Souro SANOU University Hospital of Bobo-Dioulasso in recent years[16,17].

The mean age of patients was 53.6 ± 11.2 years. While this result was similar to that observed by Semporé et al. in Burkina Faso, who found an average age of 54.8 ± 11.4 years[12], it differed from that observed in the study reported by Mahé et al.[6] who found an older population, with an average age of 61.4 ± 11.3 years. Overall, our population is younger than that of the western countries. However, lifestyles in sub-Saharan Africa are changing rapidly, with increasing an urbanization, a westernized diet richer in fats and sugars, and an increasing physical inactivity, all of which are contributing to the rise in vascular disease even in young populations.

The main cardiovascular risk factors found among patients were sedentary lifestyle (62.2%), overweight/obesity (58.2%), diabetes (52.0%), arterial hypertension (64.3%), hypercholesterolemia (11.2%), and smoking (8.2%). This distribution is representative of the population at risk of developing obliterative arteriopathy of the lower limbs. These cardiovascular risk factors found in patients are recognized as contributors of peripheral circulation damage[18,19].

The majority of patients were at stage 4 of the Leriche and Fontaine classification, with trophic disorders, indicating a consultation at the complication stage of arterial disease in our population with limited resources. Semporé et al. found that diabetics at the complication stage were consulted late[12]. Access to medical care in many parts of sub-Saharan Africa like ours remains limited, and this complicates the prevention, early diagnosis and management of vascular disease. The lack of healthcare infrastructure, the shortage of qualified healthcare professionals, and the economic difficulties of the population hamper the early management of cardiovascular disease.

Concerning the relationship between HRR1 and clinical severity of ischemia, a statistically significant difference was observed ($p < 0.0001$) in HRR1 between the different patient groups. Patients in Group IV (severe ischemia with severe intermittent claudication) showed the smallest HRR1 (11 ± 8 bpm), while those in Group I (asymptomatic atheromatosis) had a highest HRR1 (20 ± 10 bpm). These results were found by Mahé et al[6] and Depairon and Zicot[20]. The work of Coulibaly et al also revealed that an alteration in the post-exercise period was associated with the presence of severe ischemic heart disease[11]. These findings suggest that post-exercise HRR is slower and less marked in patients with severe ischemia, which may reflect greater impairment of peripheral perfusion and vascular functional capacity.

In terms of the relationship between walking distance and severity of ischemia, walking distance was significantly shorter in patients with more severe ischemia. Patients in Group IV (severe claudication) walked 224 ± 115 m, while those in Group I (asymptomatic atheromatosis) walked 443 ± 59 m, reflecting the limits imposed by ischemia on physical performance. Our results collorated with those of Mahé et al[6]. This observation in our study reinforces the idea that severe intermittent claudication is strongly associated with a reduction in functional capacity, measured here by the distance covered during the 6-minute walking test. An imbalance and dysfunction of autonomic nerve regulation appears to exist in our patients, as has been found in other studies[21,22]. This is manifested by impaired vagal reactivation and increased sympathetic activity at peak exertion[22,23]. This phenomenon is thought to be responsible for the slight decrease in heart rate during recovery and an altered chronotropic response[24].

HRR1 appears to be a valuable functional indicator for assessing the severity of lower limb ischemia in patients with LEAD. Slower heart rate recovery after exercise could be a sign of deterioration in peripheral perfusion, which may help stratify the management of these patients.

Walking distance is also a good indicator of functional function and exercise tolerance, with a notable decrease in patients with severe ischemia.

Study limits

Our study has some limitations, as it was conducted in a single hospital-based center. Further studies would be required to verify the external validity of the results (generalization to other patient populations). We used a 6-minute walk test in our study, it is not possible to extend our results to all exercise procedures as the HRR1 response depends on the mode of exercise.

Studies should also be conducted to provide direct evidence of sympathetic nervous system activity.

Despite these limitations, our study shows that HRR1 could be used as a simple and rapid clinical marker to assess the severity of ischemia in daily clinical practice in our resource-limited setting. Complementary to the gait test, this parameter could offer additional information for patient follow-up and treatment management, including vascular rehabilitation.

Conclusion

Our study highlights a significant relationship between HRR1 after a 6-minute walk test and the severity of lower limb ischemia, as measured by the Fontaine's classification. The results suggest that patients with slower heart rate recovery (indicator of severe ischemia) also have a shorter walking distance covered, confirming the functional impact of ischemia on exercise tolerance. This could potentially lead to improved management strategies for peripheral arterial disease based on post-exercise cardiac recovery.

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Ethical clearance: the research protocol was conducted under N°2020588/MS/SG/CHUSS/DG obtained from authorization of the General Management and the CHU Souro SANOU ethics committee.

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