

Clinical impact of a structured exercise-training program in a sample of North African male patients with stable angina: A pilot study

Impact clinique d'un programme d'entraînement physique chez des patients nord-africains atteints d'angine stable: Etude pilote

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ABSTRACT

Introduction: No previous Tunisian or North African study, till September 2025, have evaluated the value and necessity of an exercise-training program (ETP) as crucial therapeutic strategies for patients with stable coronary artery disorders. The main aim of the present study was to evaluate the effects of an ETP on exercise data determined during the 6-min walk test (6MWT) and treadmill stress test in patients with stable angina.

Methods: This prospective experimental pilot study was carried out at Farhat Hached cardiology, and physiology and functional explorations departments (Sousse, Tunisia). Eleven males who had stable angina for longer than three months were included in the study. The Karvonen formula was used to establish the intensity of the ETP, which included 24 sessions of combined endurance and resistance training (three sessions per week for eight weeks). Physical fitness data determined during the 6MWT and treadmill stress test were evaluated pre- and post- ETP.

Results: When comparing pre- and post-ETP assessments, there were significant changes in i) 6-min walk distance (+ 61m), resting heart rate (-9 bpm), and end walk systolic blood pressure (+ 4.25 mmHg) determined during the 6MWT, and ii) maximal heart rate (+9 bpm), speed (+ 1.41 km/h), elevation of the treadmill slope (+ 2.25%), and bearing (+ 0.91) determined during the treadmill stress test.

Conclusion: Patients with stable angina were able to exercise more effectively thanks to ETP.

Key words: 6MWD, Blood Pressure, Cardiac Rehabilitation, Coronary Angiography, Exercise capacity; Exercise Tolerance; Physical Fitness, Prospective Studies

RÉSUMÉ

Contexte: Aucune étude tunisienne ou nord-africaine n'a, jusqu'à septembre 2025, évalué la valeur et la nécessité d'un programme d'entraînement physique (PEP) en tant que stratégie thérapeutique essentielle chez les patients atteints de coronaropathie stable. L'objectif principal de la présente étude était d'évaluer les effets d'un PEP sur les paramètres d'effort déterminés lors du test de marche de six minutes (TM6) et de l'épreuve d'effort sur tapis roulant chez des patients présentant une angine de poitrine stable.

Méthodes: Cette étude pilote prospective expérimentale a été menée dans les services de cardiologie, et de physiologie et d'explorations fonctionnelles de l'hôpital Farhat Hached (Sousse, Tunisie). Onze hommes, présentant une angine de poitrine stable depuis plus de trois mois, ont été inclus. L'intensité du PEP a été déterminée selon la formule de Karvonen. Le programme comprenait 24 séances combinant exercices d'endurance et de résistance (trois séances par semaine, durant huit semaines). Les données de condition physique recueillies lors du TM6 et de l'épreuve d'effort ont été évaluées pre- et post- le PEP.

Résultats: La comparaison des données pré- et post-PEP a mis en évidence des améliorations significatives: i) lors du TM6 : augmentation de la distance parcourue (+ 61 m), diminution de la fréquence cardiaque de repos (- 9 bpm) et élévation de la pression artérielle systolique en fin de test (+ 4,25 mmHg) ; ii) lors de l'épreuve d'effort : augmentation de la fréquence cardiaque maximale (+ 9 bpm), de la vitesse (+ 1,41 km/h), de la pente du tapis (+ 2,25 %) et de la charge supportée (+ 0,91).

Conclusion: Chez les patients atteints d'angine stable, la mise en place d'un PEP a permis une amélioration significative de la tolérance à l'effort.

Mots-clés : 6MWD ; Pression Artérielle ; Réadaptation Cardiaque ; Angiographie Coronaire ; Capacité d'Exercice ; Tolérance à l'Effort ; Condition Physique ; Études Prospectives

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INTRODUCTION

The world has witnessed an epidemiological transition characterized by a decline in infectious diseases in favor of non-communicable diseases [1]. Among these, cardiovascular diseases (CVDs) are the leading cause of death worldwide, with coronary artery disease being predominant [2]. In Tunisia, according to the World Health Organization, non-communicable diseases account for 82% of all deaths, with CVDs representing 49% [3]. These diseases are expected to remain the leading cause of death by 2030 [4], with nearly 23.6 million people projected to die from CVDs, mainly heart disease and stroke [4]. In addition to pharmacological treatments and interventional cardiology, lifestyle modifications including regular physical exercise and cardiac rehabilitation (CR) are highly recommended for managing CVDs [3, 4].

CR is a multifactorial intervention endorsed by international guidelines for patients with coronary artery disease [3, 5]. CR has been shown to reduce mortality, hospitalization and healthcare costs, while improving exercise capacity, and quality of life [4]. The core components of CR include patient assessment and education, physical activity and dietary counseling, exercise training, risk factor control, psychosocial management, and vocational advice guidance [6]. Traditionally, CR is divided into three phases: i) Phase I, an inpatient service focusing on early mobilization, brief counseling on the illness, treatment, risk factor management and follow-up planning [5], ii) Phase II, a primarily supervised outpatient ambulatory program [6, 7], and iii) Phase III, a lifelong maintenance phase aimed at managing risk factors through lifestyle changes and an exercise training program (ETP) [6]. In Tunisia, to the best of the authors' knowledge, no previous study has evaluated the effect of an ETP on anthropometric, metabolic, physical exercise, and quality of life data of patients with stable angina. In fact, the consultation of PubMed on September 18, 2025 using the combination of (Cardiac rehabilitation [Title/Abstract]) AND (Tunisia [Title/Abstract]) revealed no published study.

The aim of the present study was to assess the effects of an 8-week, standardized and individualized ETP on cardiovascular risk factors, physical fitness, and both physical and psychological well-being in Tunisian patients with stable angina. The primary endpoint of the study was the improvement in submaximal aerobic capacity and exercise tolerance, assessed through the 6-min walk test (6MWT). As a pilot investigation, this work underscores the role of an ETP as a pivotal component of comprehensive care for patients with stable angina.

METHODS

Study design

This prospective, experimental pilot study was conducted at the Departments of cardiology and physiology and functional explorations at Farhat Hached University Hospital (Sousse, Tunisia). The ETP was done over an

8-week period, from December 15, 2022, to February 15, 2023. Ethical approval was obtained from the hospital's ethics committee (approval number: FH/1306/2021). All participants provided written informed consent after receiving detailed information about the study objectives, procedures, and potential benefits.

Study population

Figure 1 presents the study flowchart. Only male patients aged more than 50 years, with a stable angina diagnosed more than three months before the inclusion in the study were included. The sampling was done based on a convenience method. The patients' recruitment was done in two ways. First, the medical records of patients with angina that were followed in the aforementioned cardiac department were verified, and patients fulfilling the inclusion criteria were contacted by phone. Second, some patients were directly addressed by two cardiologists (IB and DD in the authors' list) from the aforementioned cardiac outpatient. At the beginning of the study, an information letter, covering details about the project and visit dates, was given to the patients. The non-inclusion criteria were: Unstable angina; myocardial ischemia; uncontrolled high blood pressure (ie; systolic blood pressure (SBP) >250 mmHg - diastolic blood pressure (DBP) >120 mmHg); orthostatic hypotension; pacemaker; osteoarticular pathology; respiratory pathology causing dyspnea such as chronic obstructive pulmonary disease and asthma; neuromuscular pathology; and inability to give informed written consent.

Medical records of patients presenting contraindications to exercise testing or missing one training session were excluded from the statistical final analysis [8]. To avoid confusing effects, patients with unstable angina within four weeks prior to the beginning of the study were not included. Unstable angina is a clinical syndrome characterized by myocardial ischemia without sustained ST-segment elevation or biochemical evidence of myocardial necrosis. It typically presents with new-onset, rest, or crescendo-pattern chest pain, and is associated with a high risk of progression to myocardial infarction [9].

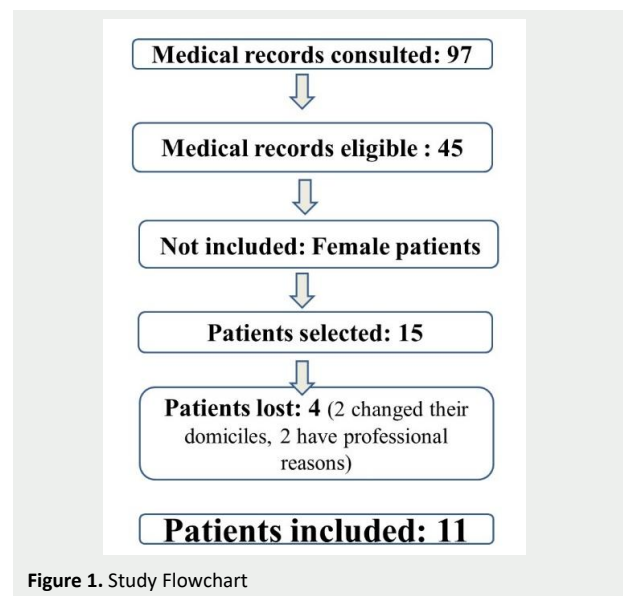


Figure 1. Study Flowchart

Collected data

The study comprises four visits: two (V1 and V2) pre-ETP and two (V3 and V4) post-ETP. Each two visits were separated by a 24 hours interval.

During V1, patients signed the consent, and the following four questionnaires were applied: pre-established medical questionnaire, modified British medical research council (mMRC) scale for dyspnea [10], Voorrips physical activity questionnaire [11], and hospital anxiety and depression (HAD) scale [12]. Questions were asked in the Tunisian dialect by only one cardiologist (IB in the authors' list). Moreover, the following exams were also performed: Clinical exam, anthropometric data, electrocardiogram (ECG), transthoracic cardiac ultrasound, and venous blood sample after 12 hours of fasting. During V2, the following tests were performed: treadmill stress test and 6MWT. During V3, same exams done during V1 were performed, except the consent signing. During V4, same exams done during V2 were performed.

Procedures and applied definitions

Clinical data

Clinical data were collected from a pre-established medical questionnaire, usually applied in the routine activity [13]. Clinical data included the following information: age (years), personal medical history, medication intake, lifestyle (ie; alcohol- and tobacco-use, sedentary lifestyle), characteristics of the angina (ie; discovery date, treatments, coronary angiography (ie; number of stenosed coronary arteries) and transthoracic cardiac ultrasound (ie; diameters of the different cavities, walls' thickness, ventricular ejection fractions, existence of a pericardial effusion)). Cigarette-smoking was assessed in packs-year.

The coronary angiography exam, performed during the last 30 days before inclusion in the study, allows to classify patients into two subgroups (ie; one stenosed coronary artery; more than one stenosed coronary arteries). Dyspnea was evaluated according to the mMRC scale [10]. A translated (non-validated) version of the Voorrips physical activity questionnaire was filled out by each patient, and household, sporting, and leisure activities were evaluated to yield a total physical activity score [11]. According to the total physical activity score (ie; the sum of the household, sporting, and leisure activities scores), two groups of patients were retained: sedentary (score < 9.4) and active (score ≥ 9.4). A translated (non-validated) version of the HAD [12] was used to evaluate the status of depression and anxiety [14].

Anthropometric and ECG data

Age (Yr) was verified by the identity card. Height (± 0.01 m) was measured with a mobile stadiometer with shoes removed, heels joined and back straight. Weight (± 1 kg) was measured with patients lightly dressed, and body mass index (BMI, kg/m²) was calculated. The following definitions related to the corpulence status were adopted [15]: underweight (BMI < 18.5 kg/m²), normal weight (BMI: 18.5-24.9 kg/m²), overweight (BMI: 25.0-29.9 kg/

m²), obesity (BMI ≥ 30.0 kg/m²).

A 12-lead resting electrocardiogram was performed at baseline. The following data were collected: heart rate (bpm), heart axis, QT space (ms), corrected QT (CQT, ms). QT was considered long when it was > 440 ms [16]. Analysis of ventricular repolarization, which is a predictor of ventricular arrhythmia and sudden cardiac death, was performed through calculation using Bazett's formula of the CQT [16].

Biological data

The blood sample was collected using a 20-ml syringe, upon completion of the ECG. The blood sample was treated in the Biochemistry laboratory (Farhat Hached Hospital of Sousse, Tunisia). Blood sample was divided into three tubes: i) Fasting glycaemia (mmol/L); ii) Glycated hemoglobin (HbA1c, %), iii) Total cholesterol (mmol/L); low- and high- density lipoprotein cholesterol (LDL-C, HDL-C, respectively, mmol/L), triglycerides (mmol/L). Triglycerides was quantified by the colorimetric method. Fasting glycaemia, total cholesterol, HDL-C, were quantified by spectrophotometry [17]. LDL-C was calculated [18]: LDL-C = Total cholesterol – HDL-C – Triglycerides/5.

Maximal aerobic capacity: Treadmill stress test

The treadmill stress test measures the maximum aerobic capacity in terms of heart rate [19]. This test, which estimates indirectly the maximal oxygen consumption, was conducted by a cardiologist (IB in the authors' list) in an onsite emergency cart. A treadmill at measurable and adjustable speed and slope was used. An ECG with recording of the 12 standard leads was used to monitor heart rate. A sphygmomanometer and a stethoscope were used to measure SBP and DBP. The stress test was performed according to Bruce's protocol with increased load per step [20]. The test was maintained until the patient got exhausted or a stop criterion appeared [21]. The following data were collected: Resting and maximal heart rate (bpm), speed (km/h), slope (%), and bearing.

Submaximal aerobic capacity: 6MWT

The 6MWT, which explores the sub-maximum aerobic capacity, is the most widely used field test in the cardiorespiratory domain [24]. Only one 6MWT was conducted outdoors according to international guideline [23-25]. Patients were told to eat a light meal, to avoid vigorous exercise in the two hours prior to testing and to wear comfortable clothes and appropriate walking shoes [23]. The 6MWT was conducted along a seldom-traveled, flat, straight corridor (40 m long, marked every one meter with cones to indicate turnaround points) with a hard surface. To minimize intraday variability, temperature effects, and biological rhythms, the 6MWT was performed during the morning, a period characterized by a stable ambient temperature of 12-20°C. All patients performed the 6MWT for the first time with no warm-up period and no encouragement. However, patients were informed that they are allowed to stop and rest during the test. The patients sat in a chair located near the starting position for at least 10 min before the test

started. During this time, resting dyspnea, heartrate and oxy-hemoglobin saturation (oxy-sat), SBP and DBP were measured. The test instructions to the patients were those recommended by international societies [23-25]. At the end (t_{End}) of the 6MWT, the same data, in addition to the 6MWD, were measured. Recommended reasons for immediately stopping the 6MWT include the following: chest pain, intolerable dyspnea, leg cramps, staggering, diaphoresis, and pale or ashen appearance [23]. In addition to 6-min walk distance (6MWD, m), dyspnea (visual analogous scale (VAS)), SBP and DBP (mmHg), heart rate (bpm), oxy-sat were noted/calculated. Dyspnea during the 6MWT was evaluated by the VAS, which allows an easy evaluation of exercise dyspnea [26]. Dyspnea was then quantified from zero (no breathlessness) to ten (maximum of breathlessness).

Exercise-training program

The ETP was conducted over eight weeks at a rate of three sessions per week, and each session lasted 60 minutes. Resistance and endurance training types were mixed during the ETP[22, 27-30]. The intensity of the exercise training corresponds to the target heart rate range calculated according to the Karvonen formula [31, 32]: Intensity = Resting heart rate+ [(maximal heart rate - resting heart rate) x K], with K is equal to 0.8 or 0.6 for patients treated or not by β -blockers. The heart rate was continuously monitored (heart rate monitor; Polar S810 - Finland) to allow patients to train within the target heart rate range ± 5 bpm. A typical session includes two parts. The first part of the ETP involves an endurance-training program comprising the following three steps [31, 33-35]: i) Warming up on the ground, then on treadmill or ergocycle (10 minutes) with a progressive increase in heart rate; ii) Proper training (30 minutes) on a treadmill or on an ergometric bicycle. The patient progressively achieves the target heart rate range. At this stage, the patient was asked to maintain pedaling or accelerated walking for 30 minutes on the plateau [31, 33, 34]; iii) Active recovery on a treadmill (decrease in speed and slope) or on an ergometric bicycle (decrease in power), preventing hypotensive discomfort at the end of exercise due to a sudden drop in cardiac output [35].

The second part of the ETP comprises a resistance-training program. The latter is a selective segmental work against resistance determined from maximum load or maximum repetition, known as maximum weight that can be lifted once [36]. In practice, it consists in a succession of repetitive movements at low intensity (30 to 50% of the maximum force developed) [36]. The resistance training program involved multiple sets of 10 to 15 repetitions. Specifically, patients performed two sets per exercise. A recovery period of approximately 90 seconds was allowed between sets to optimize the training load and facilitate physiological adaptations. This rest interval was chosen based on evidence indicating its effectiveness in balancing muscular endurance and strength gains, which are critical for cardiac rehabilitation patients[36].Figure 2 details the study design of the ETP.

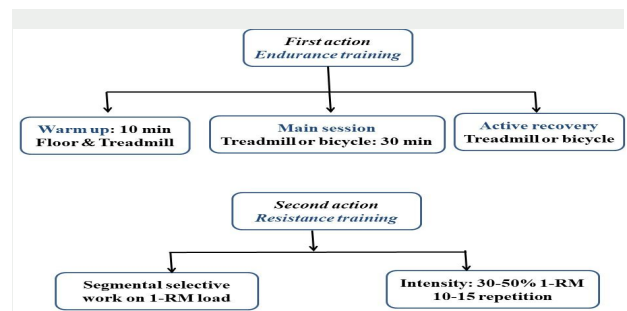


Figure 2. Study design of the training intervention.

RM: repetition maximum.

Statistical analysis and sample size calculation

Sample size

The sample size was appraised according to the following formula [37]: $N = (Z_{\alpha/2})^2 s^2/d^2$, where

- " $Z_{\alpha/2}$ " is the normal deviate for one tailed alternative hypothesis at a level of significance ($Z_{\alpha/2}$ equal to 2.33 at an error rate of 0.01%);
- " s " is the standard deviation (SD = 45.14 m); and
- " d " is the accuracy of estimate or how close it is to the true mean (= 32.63 m).

The " s " and " d " data were collected from a previous work including cardiac patients [38], where the 6MWD values were 357 ± 117 m and 409 ± 115 m, respectively, pre-and post- an ETP.

The appraised sample size as $N = (2.33)^2 45.14^2 / 32.63^2$ gives a sample of 11 patients. The assumption of 25% for nonattendance during the post-ETP session gives a revised sample of 14 patients ($15 = 11 / (1.0 - 0.25)$).

Statistical analysis

The distribution of data was assessed using the Kolmogorov-Smirnov test. When the distribution was normal and variances were equal, results were presented as mean $\pm$ SD. Otherwise, results were expressed as median (interquartile). A non-parametric test (Wilcoxon paired pair test) was used to compare the quantitative data determined pre6- and post- ETP. Data entry was performed using the Statistica software (Statistica Kernel version 6; Stat Soft, France). The significance level was set at $p < 0.05$.

RESULTS

Descriptive data

Fifteen patents were initially included, and four leaved the ETP for professional reasons and change of domicile (Figure 1). The final sample included 11 male patients with stable angina (mean $\pm$ SDof age and BMI were 57 ± 9 years and 27.5 ± 4.2 kg/m², respectively).Two, eight, and five patients have a sedentary lifestyle, were overweight, and were active smokers (mean $\pm$ SD cigarette consumption = 10 ± 13 packs-year), respectively.

Analysis of the cardiovascular risk factors identified a personal history of i) Type 2 diabetes mellitus in six patients (mean $\pm$ SD duration of oral antidiabetics = 13 ± 12 years, three received a combination of insulin and oral

antidiabetics, HbA1c > 7% in 2 patients), ii) Arterial hypertension in five patients (Three were unbalanced, with a mean±SD duration of angiotensin-converting enzyme inhibitor (ACEI, n=4) or calcium channel blockers (n=1) = 4±4.4 years), and iii) Dyslipidemia in eight patients (All were unbalanced, mean±SD duration of statin use = 4.6±4.4 years).

The mean±SD (range) discovery time of the coronary insufficiency was 16±11 (4 to 36) months. Coronary involvement distribution was multi-vascular (72%) or mono-vascular (28%) not requiring a revascularization procedure in any way. All patients were on antiplatelet therapy and on statin. Previous treatments were associated with ACEI and β-blocker in six and seven patients, respectively (Table 1).

No patient had pulmonary arterial hypertension or valvulopathy. All patients had normal pericardium and right chambers. Table 2 presents detailed data concerning the trans-thoracic echocardiography data of the patients.

Table 1. Distribution of patients according to their anti-ischemic treatment (n=11).

Anti-ischemic treatment	Other medicaments	Number
APT + statin+	Nothing	1
	β-blocker	1
	CEI	1
	Calcium antagonists	2
	β-blocker + ACEI	5
	β-blocker + calcium antagonists	1

ACEI: Angiotensin-converting enzyme inhibitor. APT: Antiplatelet therapy. CEI: Converting enzyme inhibitor

Table 2. Transthoracic echography data (n=11).

Patient N°	Left ventricular ejection fraction (%)	Left atrium diameter (mm)	Interventricular septum (mm)	Telediastolic diameter (mm)
1	65	34	9	48
2	64	39	9	55
3	78	33	12	49
4	66	18	11	53
5	70	41	13	54
6	68	17	12.5	56
7	71	19	10	50
8	75	16	10	51
9	74	17	10.5	54
10	56	23	13.5	59
11	62	17	13	51

Analytical data

ETP had no significant effect on anthropometric or biological (Table 3) data.

Table 4 exposes the effects of ETP on ECG data. During the pre-ETP, ECG revealed i) Normal heart axis in 10 patients, ii) Heart axis deviation to the right in one patient, iii) At least one conduction disorder in seven patients (Incomplete left bundle branch block type in 4 patients), iv) At least one repolarization disorder in four patients, indicating,

in the majority of cases, an epicardium ischemia with a negative T wave (n=3) associated with a flattening of the R wave in two patients, and v) Corrected QT long in one patient. The mean corrected QT was 411.9 ms. During the post-ETP, ECG revealed i) Heart axis deviated to the right in one patient, ii) Persistence of conduction disorder in six patients with disappearance of the disorder in one patient, iii) Repolarization disorder in four patients with negative T wave (n=3) associated with a flattening of the R wave (n=2). The mean corrected QT was almost unchanged = 413.35 ms.

Table 5 presents the effects of the ETP on 6MWT data. Comparisons between pre- and post- ETP revealed that: i) 6MWD increased significantly by 61 m; ii) Heart rate_{Rest} decreased significantly by nine bpm; and iii) SBP_{End} increased significantly by 4.25 mmHg.

Table 3. Anthropometric and biological data determined pre- and post- exercise training program (ETP)(n=11).

Data	Unit	Pre-ETP	Post-ETP
Height	m	1.74±0.06	1.74±0.06
Weight	kg	83.3±10.9	82.5±10.4
Body mass index	kg/m ²	27.5±4.2	27.2±3.9
Fasting glycaemia	mmol/l	7.02±2.57	7.15±2.99
Glycated hemoglobin	%	6.81±1.09	6.78±0.92
Total cholesterol	mmol/l	4.33±1.17	4.43±0.97
High-density lipoprotein cholesterol	mmol/l	1.08±0.34	1.14±0.24
Low-density lipoprotein cholesterol	mmol/l	2.51±0.80	2.56±0.86
Triglycerides	mmol/l	1.41±0.52	1.32±0.29

Data were mean±standard deviation.

Comparison between pre- and post- ETP (Wilcoxon paired pair test): No significant difference (p>0.05).

Table 6 presents the effects of the ETP on treadmill stress test data. Comparisons between pre- and post- ETP revealed that i) Maximal heart rate increased significantly by nine bpm; ii) Speed increased significantly by 1.41 km/h; iii) Elevation of the treadmill slope increased significantly by 2.25%, and iv) Bearing increased significantly by 0.91. In three patients, the treadmill stress test pre-ETP was electrically positive, and disappeared post-EPT in two patients. The third patient kept a positive treadmill stress test with an accentuation of the absolute value of the under-shift, going from 2.1 to 3.0 mm.

Table 7 presents the effects of the ETP on physical and psychological data. Comparisons between pre- and post-ETP revealed that: i) Leisure activity score increased significantly by 0.22, ii) mMRC decreased significantly by 0.73, and iii) Anxiety decreased significantly by 0.82.

Table 4. ECG data determined pre- and post- exercise training program (ETP) (n=11).

Pre-ETP					Post-ETP			
Patient N°	Heart axis	QT(ms)	Conduction disorders	Repolarization disorders	Heart axis	QT (ms)	Conduction disorders	Repolarization disorders
1	D II	368.89	RBBB	No	D I	383.3	ILBBB	No
2	D II	402.492	ILBBB+VES	Flattened T wave	D I	382.9	ILBBB	Early repolarization
3	D I	435.98	No	No	D I	435.9	No	No
4	AVF	435.12	ILBBB	Negative T wave	D II	391.6	ILBBB	Negative T wave
5	D II	388.84	ILBBB	Negative T wave + flattening of the R wave	D II	413.1	ILBB	Negative T wave+ flattening of the R wave
6	D II	391.61	ILBBB	No	D II	409.8	No	No
7	D II	428.48	No	No	D II	450.6	No	No
8	D II	402.49	No	Negative T wave+flattening of the R wave	D II	402.5	No	Negative T wave+ flattening of the R wave
9	D II	413.08	No	No	D II	413.1	No	No
10	D III	480.75	LPHB	No	D III	480.7	LPHB	No
11	AVF	383.24	LPHB	No	AVF	383.2	LPHB	No
Mean	-	411.9	-	-	-	413.3	-	-

AVF: Activity voltage foot. D: derivation. ILBBB: Incomplete left bundle branch block. LPHB: Left posterior hemiblock. RBBB: Right bundle branch block. VES: Ventricular extrasystol.

Table 5. Effects of the exercise training program (ETP) on 6-min walk test data determined at rest (t_{Rest}) and at the end (t_{End}) of the walk (n=11).

Session		Pre-ETP		Post-ETP	
Data	Unit	Rest	End	Rest	End
Heart rate	bpm	74±12	100±15*	65±7*	97±10*
Oxy-sat	%	97.7±1.1	98.4±1.0*	96.9±2.1	98.0±0.9*
SBP	mmHg	123.6±1.6	139.5±1.9*	130.0±1.5	172.1±1.9**
DBP	mmHg	69.1±0.7	77.3±1.0*	72.1±0.6	82.1±0.9*
Dyspnea VAS	No unit	0.36±0.67	1.18±1.54	0.00±0.00	1.40±1.11*
6MWD	m	597±70		658±47*	

DBP: Diastolic blood pressure. Oxy-sat: Oxy-hemoglobin saturation. SBP: Systolic blood pressure. VAS: Visual analog scale. 6MWD: 6-min walk distance.

Data were mean±standard deviation.

Statistical comparisons: Wilcoxon paired pair test

*p <0.05: t_{Rest} 6MWT vs. t_{End} 6MWT for the same session (ie, pre-ETP or post-ETP).

+p <0.05: t_{Rest} 6MWT pre-ETP vs. t_{Rest} 6MWT post-ETP or t_{End} 6MWT pre-ETP vs. t_{End} 6MWT post-ETP.

¥p <0.05: Pre-ETP vs. post-ETP.

Table 6. Effects of the exercise training program (ETP) on treadmill stress test data (n=11).

Data	Unit	Pre-ETP	Post-ETP
Resting heart rate	bpm	77±12	74±11
Maximal heart rate	bpm	146±9	155±6*
Speed	km/h	5.89±0.88	7.30±0.75*
Slope	%	14.66±1.28	16.91±1.22*
Bearing	No unit	3.45±0.69	4.36±0.81*

Data were mean±standard deviation.

*p (Wilcoxon paired pair test) <0.05: Pre-ETP vs Post-ETP.

Table 7. Effects of the exercise training program (ETP) on physical and psychological assessment data (n=11).

		Pre-ETP	Post-ETP
Voorrips PAQ	Daily activity score	1.57±0.36	1.56±0.37
	Sports activity score	3.94±5.24	4.60±4.86
	Leisure activity score	0.04±0.10	0.26±0.38*
	Total score	5.56±5.38	6.42±5.00
mMRC	Dyspnea	1.00±1.00	0.27±0.47*
HAD scale	Anxiety	0.82±0.75	0.00±0.00*
	Depression	0.09±0.30	0.00±0.00

HAD: Hospital anxiety and depression. mMRC: Modified medical research council scale. PAQ: Physical activity questionnaire.

Data were mean±standard deviation.

*p (Wilcoxon paired pair test) <0.05: Pre-ETP vs Post-ETP.

DISCUSSION

The present pilot study revealed that when comparing pre- and post- ETP assessments, there were significant changes in i) 6MWD (+ 61 m), heart rate_{Rest} (- nine bpm), and SBP_{End} (+ 4.25 mmHg) determined during the 6MWT, and ii) maximal heart rate (+ nine bpm), speed (+ 1.41 km/h), elevation of the treadmill slope (+ 2.25%), and bearing (+ 0.91) determined during the treadmill stress test. Moreover, comparisons between pre- and post-ETP revealed that: i) Leisure activity score increased significantly by 0.22, ii) mMRC decreased significantly by 0.73, and iii) Anxiety decreased significantly by 0.82. The aforementioned observed statistically significant improvements after retraining will translate into clinically significant benefits for the patients. These changes reflect enhanced cardiovascular efficiency, and greater exercise tolerance, which can lead to better functional capacity and reduced symptoms such as dyspnea and fatigue. Clinically, these benefits will contribute to improved quality of life, greater independence in daily activities, and potentially lower risk of adverse cardiovascular events in patients with stable angina.

Discussion of the methodology

Only male patients were included. This choice is justified by the intention to avoid changes related to hormonal status of females (such as those resulting from menopause), the ability to use the ergometric training tool, and the better adherence of males compared to females [39]. Our sample size ($n=11$) seems satisfactory as this study is the first experience of applying an ETP in North Africa patients with coronaropathy. The applied non-inclusion criteria were rigorous to form a sample of stable patients in order to minimize as much as possible the incident and accident risk, which is not zero, and to be able to perfectly manage emergency situation. Our ETP duration was eight weeks. According to the literature, a six-week period of ETP at a rate of three sessions per week is sufficient to obtain physiological and metabolic benefits [40]. A 2024 meta-analysis of 48 randomized controlled trials of coronary rehabilitation demonstrated that the duration of ETP varies from one week to 30 months with an average of 12 weeks [41]. The total number of sessions ($n = 24$) was suitable. According to the sport rehabilitation exercise group of the French society of cardiology, a minimum number of 20 sessions is necessary to obtain a significant improvement in functional capacities [36]. According to the literature, the number of sessions performed varies from three to five sessions per week [41, 42]. Combining endurance and resistance exercises in the ETP offers complementary benefits [40-42]. Endurance training improves cardiovascular function, aerobic capacity, and overall stamina, which are essential for heart health and daily activities [40-42]. Resistance training enhances muscular strength, endurance, and metabolic function, helping to improve physical performance and reduce frailty [40-42]. Together, these exercise modalities provide a more comprehensive approach, promoting better functional capacity, improving quality of life, and reducing the risk of cardiovascular events more effectively than either type alone [40-42].

Discussion of the results

Effects on anthropometric data

Our ETP had no effect on weight or BMI. These results are consistent with those of Pavy and Caillon [43] who, after six months of a CR program in three groups of coronary artery patients of different ages, identified that patients' BMI and waist circumference remained unchanged [43]. The Euroaspire III survey ($n=76$ centers in 22 European countries) [44], which was conducted on patients having coronary event or revascularization before the age of 80, reported comparable results.

Effects on blood pressure

While our ETP had no significant effect on resting SBP or DBP, SBP_{End} increased significantly by 4.25 mmHg. These results are intermediate with those reported in the literature [45, 46]. Many studies identified positive and significant effects of physical activity on SBP or DBP [47, 48]. According to a 2005 meta-analysis, the average

decrease in blood pressure in hypertensive patients is 6.9 mmHg for BSP and 4.9 mmHg for DBP [45]. This effect is comparable or even superior to that of drug monotherapy [46].

Effect on biological data

Our ETP had no significant effect on biological data. Our findings related to the lipid balance are comparable to those reported in a 2011 meta-analysis [49]. This may be due to the lack of dietary advice to reduce saturated fat, and to favorably modify the eating habits. Our findings related to the carbohydrate data are close to those reported by Tessier et al. [50] who, after 16 weeks of aerobic training, did not find any significant changes on HbA1c values between the control and the training groups.

Effects on ventricular repolarization

Our study population did not present long QT syndrome and after eight weeks of ETP, and the CQT remained almost unchanged. According to Genovesi et al. [51], training reduces CQT by reducing vagal activity at the ventricular level. Yet, this effect is only identified with a more or less long duration of ETP [52, 53].

Effects on left ventricular function

ETP plays a role in adapting central hemodynamic through its impact on the left ventricle remodeling and on the improvement of the ejection volume [54]. Giannuzzi et al. [54] studied the effect of CR in post-infarction patients, and confirmed an improvement in cardiac function without deterioration or enlargement of the left ventricle. In addition, one of the most rapid adaptations caused by aerobic exercise is hyperemia. This directly affects the volume of systolic ejection since the ventricles have better filling, thus increasing the contractility of the latter [55, 56].

Effects on physical fitness

After eight-weeks of the ETP, we noted a significant increase in the 6MWD by 61 m and a decrease in heart rate_{Rest} by nine bpm. The observed improvement in the 6MWD, exceeding the 33 m threshold recognized as clinically meaningful (ie, clinical minimal important difference) by scholarly societies [23-25], not only reflects enhanced cardiorespiratory and vascular function but may also translate into tangible benefits in patients' daily activities and overall functional capacity. These findings suggest that even moderate gains in exercise performance can have meaningful clinical relevance in this population. Indeed, it was reported in the study conducted by Gardiner et al. [57] as well as the study of Pavy et al. [58], a significant increase in 6MWD by 36 and 80m, respectively. In a 2012 meta-analysis (12 trials, 2487 subjects), a 60.43 m mean difference in 6MWD was noted after CR [59]. In two comparable studies, 6MWD improvements of 147 and 91 m were observed after CR [60, 61].

Maximum aerobic capacity (evaluated on the basis of the speed and the slope reached at the end of the treadmill stress test) showed significant improvement, with a

statistically significant difference in the heart ratemax, plateau reached at the end of the stress test, unwinding speed and slope elevation of the carpet. Our results are consistent with those of several studies concluding that ETP has a statistically and clinically significant effect on maximum aerobic capacity [58-60, 62]. Khelifa et al.[63], reported an improvement in maximum physical capacity in patients with coronary diseases, which was translated by the evaluation of three parameters which were the workload in Watt (+ 53%), the heart ratemax (+ 58%) and the duration of the effort in minutes (+ 63%) pre- and post- CR program [63]. In addition, ETP has an anti-ischemic effect, the mechanisms of which are multiple, namely lowering the heart rate, improving endothelial function, developing collateral circulation [64, 65].

Effects on the physical and psychological assessment

CVDs have important repercussions on patients' autonomy and quality of life, being responsible for physical and psychological fatigue. Study of the ETP impact on the physical activity showed a statistically significant increase in the leisure activity score, and a significant decrease in the level of dyspnea. Similarly, assessment of the psychological state revealed a statistically significant decrease in anxiety. Comparable benefits of ETP have been reported after a short, medium or long-term period of training [66-68].

Limitations

The present study has some limitations. First, the lack of a control group is a major limitation. The lack of a control group did not allow us to 'affirm' that our results are only attributable to ETP. Second, it would have been more interesting to explore the respiratory function using additional tests, such as plethysmography, and exercise data using a cardiopulmonary exercise test in order to determine the first ventilatory threshold. Due to the unavailability of equipment in our public health hospital, these examinations were not performed. Third, it was better to express the 6MWD and heart rate data as percentage of predicted values by calculating the predicted 6MWD according to local norms [69], and the predicted maximal heart rate [70]. This method allowed to standardize the expression of the 6MWD and heart rate. Fourth, variability in cardiovascular risk factors among our male patients could have influenced the observed results by affecting individual responses to the ETP. In future studies, it is crucial to i) Account for this heterogeneity by stratifying participants based on key risk factors such as arterial hypertension, diabetes mellitus, and lipid profile, and ii) Consider multivariate analyses to control for these variables, which will help to isolate the effects of the intervention more precisely and improve the generalizability of the findings. Finally, the non-inclusion of female patients restricts the representativeness of our findings and future studies should consider both sexes to improve generalizability.

Perspectives

Integrating digital technologies - such as wearable's, mobile applications, and online coaching - into ETPs

has been shown to improve exercise capacity, enhance adherence, and support the personalization of treatments [71-73]. In particular, weekly online coaching and real-time monitoring devices have demonstrated strong potential to increase physical activity intensity. Furthermore, combining innovative approaches (eg; ETP with CR) with advanced artificial intelligence-driven analyses opens promising pathways to further optimize outcomes for diverse populations living with coronary artery disease [74].

CONCLUSION

CVDs remain a major public health challenge due to their high incidence, morbidity, mortality, and overall health burden. Beyond pharmacological treatments, ETPs play a pivotal role in improving functional capacity and quality of life in patients with coronary artery disease. Our findings highlight that even an eight-week structured program can lead to significant improvements in exercise performance, as evidenced by the 6MWD and graded exercise test, reinforcing the importance of integrating such interventions into standard care.

LIST OF ABBREVIATIONS

ACEI: Angiotensin-converting enzyme inhibitor
BMI: Body mass index
CQT: Corrected QT
CR: Cardiac rehabilitation
CVD: Cardiovascular disease
DBP: Diastolic blood pressure
ECG: Electrocardiogram
ETP: Exercise-training program
HAD: Hospital anxiety and depression
HbA1c: Glycated hemoglobin
HDL: High-density lipoprotein
LDL: Low-density lipoprotein
mMRC: modified British medical research council
Oxy-sat: Oxy-hemoglobin saturation
SBP: Systolic blood pressure
SD: Standard deviation
VAS: Visual analogue scale
6MWD: 6-min walk distance
6MWT: 6-min walk test

ACKNOWLEDGMENTS. The authors would like to i) Thank the staff of the cardiology department of Farhat Hached hospital (Sousse, Tunisia), and ii) Express their sincere gratitude to the reviewers for their excellent feedback, which has substantially improved the quality of this work. Their insightful comments and constructive suggestions were invaluable in refining our manuscript [75].

DECLARATION. The authors wish to clarify that a generative artificial intelligence tool (ChatGPT ephemer) was employed to improve the manuscript's clarity and coherence in writing. Its use was strictly limited to language refinement, ensuring the text remained clear and coherent without modifying the scientific content or generating any new text [76].

SOURCES OF SUPPORT IN THE FORM OF GRANTS. The present study was financially supported by the Ministry of Higher Education and Scientific Research, Tunisia.

REFERENCES

1. Mammeri A, Tebaibia A. Cardiometabolic risk in Algeria: past and present. *Intern Emerg Med.* 2020;15(4):531-5.
2. Henry P. Pourquoi et comment optimiser la prise en charge

- de l'angor stable en 2010?: Besoins médicaux et options thérapeutiques. *AMCPV-Pratique*. 2010. 19: S7-S9.
3. Balady GJ, Williams MA, Ades PA, Bittner V, Comoss P, Foody JM, et al. Core components of cardiac rehabilitation/secondary prevention programs: 2007 update: a scientific statement from the American heart association exercise, cardiac rehabilitation, and prevention committee, the council on clinical cardiology; the councils on cardiovascular nursing, epidemiology and prevention, and nutrition, physical activity, and metabolism; and the american association of cardiovascular and pulmonary rehabilitation. *Circulation*. 2007;115(20):2675-82.
 4. Graham I, Atar D, Borch-Johnsen K, Boysen G, Burell G, Cifkova R, et al. European guidelines on cardiovascular disease prevention in clinical practice: executive summary. Fourth Joint Task Force of the European Society of Cardiology and other societies on cardiovascular disease prevention in clinical practice (constituted by representatives of nine societies and by invited experts). *Eur J Cardiovasc Prev Rehabil*. 2007; Suppl 2:E1-40.
 5. Wang L, Mei F, Min M, He X, Luo L, Ma Y. Adoption of the cardiopulmonary exercise test in the exercise ability and cardiopulmonary function rehabilitation of coronary artery disease (CAD) patients. *BMC Cardiovasc Disord*. 2024; 24(1):313.
 6. Perk J, De Backer G, Gohlke H, Graham I, Reiner Z, Verschuren M, et al. European guidelines on cardiovascular disease prevention in clinical practice (version 2012). The fifth joint task force of the European society of cardiology and other societies on cardiovascular disease prevention in clinical practice (constituted by representatives of nine societies and by invited experts). *Eur Heart J*. 2012; 33(13):1635-701.
 7. Waranski M, Garbsch R, Kotewitsch M, Teschler M, Schmitz B, Mooren FC. A behavioral change-based mobile intervention for promoting regular physical activity in medical rehabilitation maintenance of patients with coronary artery disease: Controlled Trial. *J Med Internet Res*. 2024; 26:e56480.
 8. Bergaoui J, Latiri I, Ben Saad H. Deficiency, incapacity and social disadvantage of patients with chronic hepatitis B: a case-control study. *Tunis Med*. 2021; 99(7):682-92.
 9. Bergmark BA, Mathenge N, Merlini PA, Lawrence-Wright MB, Giugliano RP. Acute coronary syndromes. *Lancet*. 2022; 399(10332):1347-58.
 10. Fletcher CM, Elmes PC, Fairbairn AS, Wood CH. The significance of respiratory symptoms and the diagnosis of chronic bronchitis in a working population. *Br Med J*. 1959; 2(5147):257-66.
 11. Voorrips LE, Ravelli AC, Dongelmans PC, Deurenberg P, Van Staveren WA. A physical activity questionnaire for the elderly. *Med Sci Sports Exerc*. 1991; 23(8):974-9.
 12. Zigmond AS, Snaith RP. The hospital anxiety and depression scale. *Acta Psychiatr Scand*. 1983;67(6):361-70.
 13. Riegel B, Moser DK, Glaser D, Carlson B, Deaton C, Armola R, Sethares K, et al. The Minnesota living with heart failure questionnaire: Sensitivity to differences and responsiveness to intervention intensity in a clinical population. *Nurs Res*. 2002; 51(4):209-18.
 14. Breeman S, Cotton S, Fielding S, Jones GT. Normative data for the hospital anxiety and depression scale. *Qual Life Res*. 2015;24(2):391-8.
 15. No authors listed. Obesity: preventing and managing the global epidemic. Report of a WHO consultation. *World Health Organ Tech Rep Ser*. 2000;894:i-xii, 1-253.
 16. Bazett HC. An analysis of the time-relations of electrocardiograms. *Ann Noninvasive Electrocardiol*. 1997;2(2), 177-94.
 17. Kong CR, Barman I, Dingari NC, Kang JW, Galindo L, Dasari RR, et al. A novel non-imaging optics based Raman spectroscopy device for transdermal blood analyte measurement. *AIP Adv*. 2011; 1(3):32175.
 18. Friedewald WT, Levy RI, Fredrickson DS. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. *Clin Chem*. 1972; 18(6):499-502.
 19. Casillas JM, Hannequin A, Besson D, Benaïm S, Krawcow C, Laurent Y, et al. Walking tests during the exercise training: specific use for the cardiac rehabilitation. *Ann Phys Rehabil Med*. 2013; 56(7-8):561-75.
 20. Bruce RA, Blackmon JR, Jones JW, Strait G. Exercising testing in adult normal subjects and cardiac patients. *Ann Noninvasive Electrocardiol*. 2004; 9(3):291-303.
 21. Dah, C. Evaluation of physical fitness: relevance, methods, and practical application. *Publ Med Afric*. 1994; 130: 38-42.
 22. Solway S, Brooks D, Lacasse Y, Thomas S. A qualitative systematic overview of the measurement properties of functional walk tests used in the cardiorespiratory domain. *Chest*. 2001; 119(1):256-70.
 23. Holland AE, Spruit MA, Troosters T, Puhan MA, Pepin V, Saey D, et al. An official European Respiratory Society/American Thoracic Society technical standard: field walking tests in chronic respiratory disease. *Eur Respir J*. 2014; 44(6):1428-46.
 24. ATS committee on proficiency standards for clinical pulmonary function laboratories. ATS statement: guidelines for the six-minute walk test. *Am J Respir Crit Care Med*. 2002. 1;166(1):111-7.
 25. Singh SJ, Puhan MA, Andrianopoulos V, Hernandez NA, Mitchell KE, Hill CJ, et al. An official systematic review of the European Respiratory Society/American Thoracic Society: measurement properties of field walking tests in chronic respiratory disease. *Eur Respir J*. 2014 Dec;44(6):1447-78.
 26. Sergysels R, Hayot M. Evaluation of exercise-induced dyspnea. *Rev Pneumol Clin*. 1997;53(5):278-82.
 27. Lipkin DP, Scriven AJ, Crake T, Poole-Wilson PA. Six minute walking test for assessing exercise capacity in chronic heart failure. *Br Med J (Clin Res Ed)*. 1986;292(6521):653-5.
 28. Rostagno C, Olivo G, Comeglio M, Boddi V, Banchelli M, Galanti G, et al. Prognostic value of 6-minute walk corridor test in patients with mild to moderate heart failure: comparison with other methods of functional evaluation. *Eur J Heart Fail*. 2003; 5(3):247-52.
 29. Brooks D, Solway S, Gibbons WJ. ATS statement on six-minute walk test. *Am J Respir Crit Care Med*. 2003;167(9):1287.
 30. Enright PL. The six-minute walk test. *Respir Care*. 2003; 48(8):783-5.
 31. Foulon E, Livain T, Noirclerc M. Cardiac rehabilitation after a heart attack: A comparative study between continuous and interval training. *Kinésithérapie Rev*. 2015; 15(163): 30-7.
 32. Caffray M. Strengthening and physical therapy for the cardiovascular patient. *Kine Rev*. 2010; 10(106): 30-4.
 33. Beaumont M, Le Ber C. Role of the physiotherapist in the treatment of dyspnoea. *Méd Intensive Réa*. 2016;26(1):21-30.
 34. Douard H. Cardiac rehabilitation in chronic heart failure. *Mt Cardio*. 2005; 1(6), 502-8.
 35. Meurin P, Massabie R, Renaud N, Weber H, Grosdemouge A, Tabet J. Y, et al. Intérêt de la réadaptation cardiaque chez le patient coronarien. *Sang Thromb Vaiss*. 2004; 16(9): 447-54.
 36. Monpère C. Les dernières recommandations françaises en réadaptation cardiaque: que faut-il en retenir? Link: <https://www.realites-cardiologiques.com/2013/12/11/les-dernieres-recommandations-francaises-en-readaptation-cardiaque%E2%80%89que-faut-il-en-retenir%E2%80%89/> (Last visit: September 19, 2025).
 37. Serhier Z, Bendahhou K, Ben Abdelaziz A, Bennani MO. Methodological sheet n°1: How to calculate the size of a sample for an observational study? *Tunis Med*. 2020; 98(1):1-7.
 38. Ades PA, Savage P, Cress ME, Brochu M, Lee NM, Poehlman ET. Resistance training on physical performance in disabled older female cardiac patients. *Med Sci Sports Exerc*. 2003; 35(8):1265-70.
 39. Oosenbrug E, Marinho RP, Zhang J, Marzolini S, Colella TJ, Pakosh M, et al. Sex differences in cardiac rehabilitation adherence: A meta-analysis. *Can J Cardiol*. 2016; 32(11):1316-24.
 40. Conraads VM, Pattyn N, De Maeyer C, Beckers PJ, Coeckelberghs E, Cornelissen VA, et al. Aerobic interval training and continuous training equally improve aerobic exercise capacity in patients with coronary artery disease: the SAINTEX-CAD study. *Int J Cardiol*. 2015; 179:203-10.
 41. Taylor RS, Brown A, Ebrahim S, Jolliffe J, Noorani H, Rees K, et al. Exercise-based rehabilitation for patients with coronary heart disease: systematic review and meta-analysis of randomized

- controlled trials. *Am J Med*. 2004; 116(10):682-92.
42. Denolle T, Dib M, Brune M, Nicolas S, Richard A, Auguste V, et al. Control of cardiovascular risk factors in coronary patients one year after cardiac rehabilitation. *Ann Cardiol Angeiol*. 2017; 66(3):135-9.
 43. Pavy B, Caillon M. Effects of a cardiac rehabilitation programme in coronary patient according to age. *Ann Cardiol Angeiol*. 2012; 61(5):338-44.
 44. Kotseva K, Wood D, De Backer G, De Bacquer D. Use and effects of cardiac rehabilitation in patients with coronary heart disease: results from the EUROASPIRE III survey. *Eur J Prev Cardiol*. 2013; 20(5):817-26.
 45. Cornelissen VA, Fagard RH. Effects of endurance training on blood pressure, blood pressure-regulating mechanisms, and cardiovascular risk factors. *Hypertension*. 2005; 46(4):667-75.
 46. Ketelhut RG, Franz IW, Scholze J. Regular exercise as an effective approach in antihypertensive therapy. *Med Sci Sports Exerc*. 2004; 36(1):4-8.
 47. Fagard RH. Exercise characteristics and the blood pressure response to dynamic physical training. *Med Sci Sports Exerc*. 2001; 33(6 Suppl): S484-92.
 48. Ghannem M, Ghannem L, Ghannem L. Cardiac rehabilitation after myocardial infarction. *Ann Cardiol Angeiol*. 2015; 64(6): 517-26.
 49. Lawler PR, Fillion KB, Eisenberg MJ. Efficacy of exercise-based cardiac rehabilitation post-myocardial infarction: a systematic review and meta-analysis of randomized controlled trials. *Am Heart J*. 2011; 162(4): 571-84.
 50. Tessier D, Ménard J, Fülöp T, Ardilouze J, Roy M, Dubuc N, et al. Effects of aerobic physical exercise in the elderly with type 2 diabetes mellitus. *Arch Gerontol Geriatr*. 2000; 31(2): 121-32.
 51. Genovesi S, Zaccaria D, Rossi E, Valsecchi MG, Stella A, Stramba-Badiale M. Effects of exercise training on heart rate and QT interval in healthy young individuals: are there gender differences? *Europace*. 2007; 9(1): 55-60.
 52. Drigny J, Gremeaux V, Guiraud T, Gayda M, Juneau M, Nigam A. Long-term high-intensity interval training associated with lifestyle modifications improves QT dispersion parameters in metabolic syndrome patients. *Ann Phys Rehabil Med*. 2013; 56(5): 356-70.
 53. Schuit AJ, Dekker JM, de Vegt F, Verheij TC, Rijnke RD, Schouten EG. Effect of physical training on QTc interval in elderly people. *J Electrocardiol*. 1998; 31(2): 111-6.
 54. Giannuzzi P, Tavazzi L, Temporelli PL, Corrà U, Imparato A, Gattone M, et al. Long-term physical training and left ventricular remodeling after anterior myocardial infarction: results of the Exercise in Anterior Myocardial Infarction (EAMI) trial. EAMI Study Group. *J Am Coll Cardiol*. 1993; 22(7):1821-9.
 55. Green HJ, Sutton JR, Coates G, Ali M, Jones S. Response of red cell and plasma volume to prolonged training in humans. *J Appl Physiol*. 1991; 70(4):1810-5.
 56. Denollet J, Brutsaert DL. Enhancing emotional well-being by comprehensive rehabilitation in patients with coronary heart disease. *Eur Heart J*. 1995; 16(8): 1070-8.
 57. Gardiner FW, Regan E, Nwose EU, Bwititi PT, Crockett J, Wang L. Outpatient cardiac rehabilitation: Effects on patient improvement outcomes. *Diabetes Metab Syndr*. 2017; 11 Suppl 2:S1025-S1030.
 58. Pavy B, Tisseau A, Caillon M. The coronary patient six months after cardiac rehabilitation: rehabilitation evaluation research (RER study). *Ann Cardiol Angeiol*. 2011; 60(5):252-8.
 59. Bellet RN, Adams L, Morris NR. The 6-minute walk test in outpatient cardiac rehabilitation: validity, reliability and responsiveness--a systematic review. *Physiotherapy*. 2012; 98(4):277-86.
 60. Astolfi T, Borroni F, Savic M, Gremeaux V, Millet GP. Heart rate recovery of individuals undergoing cardiac rehabilitation after acute coronary syndrome. *Ann Phys Rehabil Med*. 2018; 61(2):65-71.
 61. Januszek R, Kocik B, Siłka W, Gregorczyk-Maga I, Mika P. The effects of cardiac rehabilitation including nordic walking in patients with chronic coronary syndromes after percutaneous coronary interventions in elective mode. *Medicina (Kaunas)*. 2023; 59(7): 1355.
 62. Qin D, Liu G, Zhang J, Lin S, Liu X, Zhao J, et al. Innovative cardiac rehabilitation: Effects of adaptive postural balance exercise on coronary artery disease and type 2 diabetes. *Diabetes Metab Syndr Obes*. 2025; 18:1239-1254.
 63. Said-Aissa K, Said-Aissa S. Effets du reentrainement aérobie sur l'amélioration des indices de la performance physique en réadaptation cardiaque chez les coronariens. *Eur Sci J*. 2014; 10(33):181-94.
 64. Meurin P, Pavy B. Benefits and risks of exercise training in coronary artery disease patients. *Ann Cardiol Angeiol*. 2006; 55(4):171-7.
 65. Albustami M, Hartfiel N, Charles JM, Powell R, Begg B, Birkett ST, et al. Cost-effectiveness of high-intensity interval training (HIIT) vs moderate intensity steady-state (MISS) training in UK cardiac rehabilitation. *Arch Phys Med Rehabil*. 2024; 105(4):639-46.
 66. Chen CH, Chen YJ, Tu HP, Huang MH, Jhong JH, Lin KL. Benefits of exercise training and the correlation between aerobic capacity and functional outcomes and quality of life in elderly patients with coronary artery disease. *Kaohsiung J Med Sci*. 2014; 30(10):521-30.
 67. Yohannes AM, Doherty P, Bundy C, Yalfani A. The long-term benefits of cardiac rehabilitation on depression, anxiety, physical activity and quality of life. *J Clin Nurs*. 2010; 19(19-20):2806-13.
 68. Che Q, Zhao L, Huang B, Li H. Effects of cardiac rehabilitation on symptoms and quality of life in cardiopulmonary exercise test-positive patients with non-obstructive coronary artery disease from high altitudes. *Sichuan Da Xue Xue Bao Yi Xue Ban*. 2024; 55(6):1507-14.
 69. Ben Saad H, Prefaut C, Tabka Z, Mtir AH, Chemit M, Hassaoune R, et al. 6-minute walk distance in healthy North Africans older than 40 years: influence of parity. *Respir Med*. 2009; 103(1):74-84.
 70. Tanaka H, Monahan KD, Seals DR. Age-predicted maximal heart rate revisited. *J Am Coll Cardiol*. 2001; 37(1):153-6.
 71. Nishio R, Dohi T, Yokoyama M, Nakade T, Takahashi N, Chikata Y, et al. Wearable devices in remote cardiac rehabilitation with and without weekly online coaching for patients with coronary artery disease: Randomized controlled trial. *JMIR Mhealth Uhealth*. 2025; 13: e63797.
 72. Zhang Y, Yin X, Ren L. A randomized controlled study of enhanced external counterpulsation with cardiac rehabilitation in patients with nonobstructive coronary artery disease and coronary microvascular dysfunction. *Int Heart J*. 2024; 65(3):380-5.
 73. Isakadze N, Kim CH, Marvel FA, Ding J, MacFarlane Z, Gao Y, et al. Rationale and design of the mTECH-Rehab randomized controlled trial: Impact of a mobile technology enabled cardiac rehabilitation program on functional status and cardiovascular health. *J Am Heart Assoc*. 2024; 13(2):e030654.
 74. Saklica D, Vardar-Yagli N, Saglam M, Yuce D, Ates AH, Yorgun H. The impact of technology-based cardiac rehabilitation on exercise capacity and adherence in patients with coronary artery disease: An artificial intelligence analysis. *Arq Bras Cardiol*. 2025; 122(6):e20240765.
 75. Hidouri S, Kamoun H, Salah S, Jellad A, Ben Saad H. Key guidelines for responding to reviewers. *F1000Res*. 2024; 13: 921.
 76. Dergaa I, Ben Saad H. Artificial intelligence and promoting open access in academic publishing. *Tunis Med*. 2023; 101(6):533-6.