Techniques for Improving Exercise Routines in Response to Various Heart Conditions

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Abstract - The physical activity is fundamental to the management of numerous cardiac conditions. Nevertheless, the development of exercise protocols customised to address various cardiac conditions is an intricate undertaking. This research paper investigates the optimisation of exercise protocols with a focus on their application as a form of medicine for various cardiac conditions. Physiological benefits, risks, and considerations pertaining to exercise are examined in the context of coronary artery disease, arrhythmias, and cardiovascular disease. Healthcare providers can optimise the therapeutic benefits and guarantee the effectiveness of exercise for patients with diverse cardiac conditions by customising exercise prescriptions and comprehending the underlying mechanisms of action. Increasingly, it is acknowledged that exercise is a potent instrument for preventing and managing cardiac disease. Yet, it is imperative to customise exercise regimens for particular cardiac conditions in order to optimise advantages while reducing potential hazards. To investigates the optimisation of exercise protocols for a range of cardiac conditions, such as arrhythmias, heart failure, and coronary artery disease. Important factors to take into account encompass the nature, intensity, duration, and progression of the exercise routine. Additionally, the significance of pre-exercise screening and medical supervision for those with cardiac conditions is emphasised. Healthcare professionals can enable patients with cardiac disease to engage in physical activity in a safe manner and enhance their cardiovascular well-being through the optimisation of exercise protocols.

Keywords: Exercise, Heart Conditions, Exercise Prescription, Coronary Artery Disease, Heart Failure, Arrhythmias, Cardiac Rehabilitation.

I. INTRODUCTION

A number of chronic conditions, including cardiovascular disease, are acknowledged to be amenable to treatment and prevention through physical activity. Conversely, exercise prescription for cardiac rehabilitation (CR) programmes is not universally agreed upon, specifically with regard to the intensity of the exercises[1]. In order to ascertain the efficacy of CR programming, it is critical to ascertain the optimal exercise intensity that will augment the exercise capacity and cardiorespiratory fitness of patients afflicted with heart failure or coronary heart disease. It has been demonstrated that physical activity aids in the prevention and treatment of chronic diseases, whereas physical inactivity is a serious public health concern. In contrast, exercise compliance lags behind the recommendations made by physicians to their patients[2]. By educating physicians and promoting exercise as a component of disease prevention and treatment strategies, the Exercise is Medicine initiative attempts to bridge this gap. Psychiatric, neurological, metabolic, cardiovascular, pulmonary, musculoskeletal, and cancer are among the many conditions that have been shown to benefit from physical activity. For optimum therapeutic benefits, the prescription and intensity of exercise should be customised for each individual disease. By providing diagnostic, prognostic, and functional data, exercise testing is an essential component of cardiovascular medicine. For exercise testing to yield the greatest amount of information possible, the exercise protocol selected is critical[3].

It is recommended that individuals who have been diagnosed with specific cardiovascular diseases (CVDs) and heart failure with reduced ejection fraction (HFrEF) participate in exercise-based cardiac rehabilitation (CR), as per the guidelines of recommendation 1A [4]. This is attributable to the significant improvements in physical activity capacity, decreased rates of hospital readmissions, cardiovascular (CV) incidents, and mortality that are induced by CR. Compared to standard medical care, exercise-based CR decreased hospitalisations, CV mortality, and all-cause mortality by 31, 26, and 20%, respectively, according to systematic reviews of coronary heart disease from 2004 to 2011 [5]. In the past decade, the effectiveness of exercise-based CR in reducing all-cause mortality, recurrent CV events, and mortality from other causes has been called into question by the RAMIT (Rehabilitation after Myocardial Infarction Trial). This phenomenon sparked considerable discourse among scientists, who postulated that it might be attributed to insufficient intensity and dosage of exercise training [6]. Furthermore, meta-analyses have revealed substantial variability and insufficient elaboration with respect to the methodology employed in exercise prescription for CR programmes. A worldwide consensus regarding the duration of exercise regimens or prescriptions for CR does not exist at this time. Moreover, there is substantial variation in the recommended exercise intensities among different nations, with South America, the United States, and other European countries advocating for moderate-vigorous intensity, while Canada, Japan, the United Kingdom, and France suggest light-moderate intensity. Furthermore, a study carried out in the United Kingdom has shed light on the possibility that the exercise training intensities of patients participating in CR may fall short of the maximal range of intensities that are recommended [7].

1.1 Exercise Prescription in Cardiac Rehabilitation

Prescription practices for exercise intensity in CR vary internationally and may also be program-specific according to the resources at hand. Indicators of peak exercise capacity, anaerobic threshold, cardiac ischemia threshold, and ventilatory thresholds are all instances of objective methodologies utilised to approximate exercise intensity [8]. The presence of maximal exercise testing, preferably including cardiac gas analysis and ventilatory thresholds for intensities determined by peak oxygen consumption (VO2peak), is essential for these purposes. In programmes lacking access to maximal exercise testing, subjective assessments of exercise intensity, such as the talk test (TT) or rating of perceived exertion (RPE), are commonly employed to guide exercise intensity [9]. Indicators of Peak Exercise Capacity The prescription of aerobic exercise is recommended by the majority of exercise training guidelines in CR, as indicated by relative indices of maximal exercise capacity. Preferred exertion (Wpeak), peak heart rate (%HRpeak), VO2peak (%VO2peak), HR reserve (%HRR), and VO2 reserve (%VO2R) are some examples of such values (1, 21). As a result of their ability to incorporate the patient's quiescent values and potential suitability for patients with chronotropic incompetence, reserve calculations are commonly favoured for prescribing accurate exercise intensities [10]. Patient inability to achieve near-maximum effort, subsequent dose adjustment and timing of rate-control medications, and the fact that VO2peak or Wpeak are highly influenced by the rise rate during the test are all limitations associated with the use of relative indices of peak exercise capacity. Practical challenges also manifest in maximal exercise testing, including financial implications, inadequate technological resources, concerns regarding expertise, and the need for physician oversight [11]. An additional limitation of the workload-based approach is that, in contrast to human resources, which is determined by physiological changes such as increases in exercise capacity, progress in this methodology is contingent upon arbitrary increments.

- ❖ **Ventilatory Thresholds:** An alternative approach to utilising peak exercise capacity indicators involves establishing a correlation between exercise intensity and ventilatory thresholds. This approach, which requires cardiopulmonary gas analysis, is utilised more often in European CR programmes to prescribe exercises [12]. The terminology used to refer to these thresholds is still up for debate, and there are differing opinions on the evaluation techniques. Frequently referred to as the anaerobic threshold or first ventilatory threshold (VT1), this signifies the transition from predominantly aerobic metabolism to a stage where blood lactate accumulation commences, necessitating a greater reliance on anaerobic metabolism to sustain energy production. At this juncture, ventilation (VE) accelerates to remove the excess carbon dioxide (CO2) produced in the blood during the conversion of lactic acid to lactate [13]. The level of exercise intensity characterised by rapid accumulation of blood lactate, inability to expel excess CO2, and a disproportionate increase in ventilation efficiency (VE) in relation to CO2 production (VCO2) is referred to as the second ventilatory threshold (VT2), critical power, or lactate threshold [14]. VT1 is frequently determined using the V-slope method (i.e., the VO2 deviation from a line of identity traced across a plot of VCO2 versus VO2) or the nadir (lowest point) of the VE/VO2 to work rate relationship [15]. For the calculation of VT2, the nadir of the VE/VCO2 to work rate relationship is utilised. By extrapolating exercise training zones from these thresholds using a comparable HR or workload, one can determine the following: mild intensity below VT1, moderate intensity between VT1 and VT2, and high intensity above VT2 [16]. Threshold-based exercise prescription is associated with a number of disadvantages. There can be substantial within-subject variation between two consecutive tests (29), considerable variation among observers and locales (30), and the repeatability of VT2 in patients with CVD remains uncertain (1). Moreover, delayed VO2 response to imposed effort and decreased VO2 kinetics (1, 31) prevent immediate translation of VT thresholds to constant-load exercise [17]. These issues are exacerbated in patients with CVD and HF.

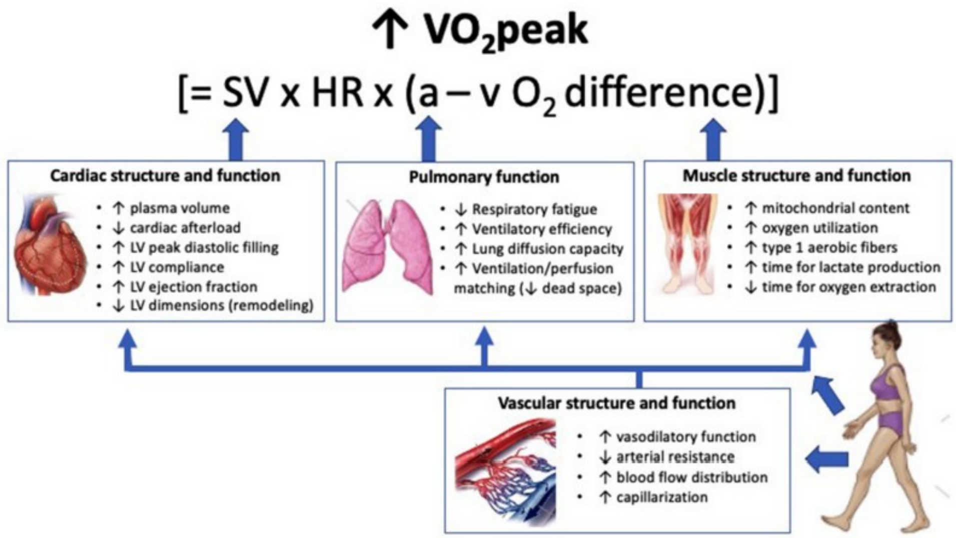


Figure 1: Physiological adaptations from exercise training

As depicted in Figure 1, this may potentially contribute to a rise in VO2peak values among individuals afflicted with cardiovascular disease or heart failure. The primary mechanism by which cardiac adaptations contribute to VO2peak improvements is by increasing stroke volume. VO2peak is influenced by pulmonary adaptations, which optimise arterial oxygen delivery and, consequently, oxygen content. VO2peak enhancements are facilitated by muscle adaptations, which increase exercise tolerance and oxygen extraction[18]. Vascular adaptations improve the distribution of blood flow, decrease arterial resistance, and increase capillary density to facilitate oxygen delivery. These modifications ultimately enhance the functionality of the cardiovascular, respiratory, and muscular systems[19]. Plasma volume increases are possible to observe within days of initiating an exercise regimen. Vasculature and skeletal muscle adaptations may manifest within a few weeks of the initiation of training. The current body of evidence provides support for the claim that HIIT results in more significant enhancements in stroke volume, mitochondrial content, and vascular vasodilatory function when compared to MICT. Despite this, the precise cardiac mechanisms that contribute to the increased volume of strokes continue to elude discovery. SV denotes stroke volume; HR represents heart rate; VO2peak signifies peak oxygen consumption; a–vO2 difference signifies the oxygen content disparity between arterial and venous blood; and LV signifies the left ventricle [20].

- **Subjective Measures**: Subjective measures of effort (e.g., RPE or TT) should be employed alongside objective measures of effort (e.g., HR or VO2) in clinical resistance (CR) settings, even when objective measures are available. This assertion holds particular validity for individuals who are incapable of acquiring a reliable or significant exercise-induced heart rate, including those afflicted with atrial fibrillation, pacemakers, chronotropic incompetence, heart transplantation, or beta blockade therapy [21]. Subjective measures can be advantageous when comparing the perceived effort of different exercise modalities [23]. Utilising a self-report scale ranging from 6 (indicating no exertion) to 20 (indicating extreme, exceedingly strenuous) to gauge patients' perceived effort during exercise, the Borg 6–20 RPE scale is a well-established tool for determining exercise intensity [22]. Practical, validated, and effective [24] is the prescribed and monitored exercise intensity method for patients with cardiovascular disease (CVD) and heart failure. Furthermore, betablocker medication does not exert any influence on this method. Possible constraints associated with the utilisation of the RPE scale encompass the impact of environmental or psychological factors, challenges encountered by patients with visual impairment, and its application during external physical activity [25]. It has also been reported that RPE is affected by exercise inexperience, level of fitness, age, gender, educational attainment, and diuretic use[26]. It is essential to provide patients with comprehensive guidance regarding the appropriate utilisation of the RPE scale. This scale integrates muscular and cardiovascular sensations and is calibrated between the extremes of "no effort" and "extremely hard/maximal effort." The TT, which is reliable and valid in patients with CVD, is an additional practical tool that can be utilised to prescribe exercise intensity [27].

1.2 Improving Exercise Routines by Various Heart Conditions:

- **Consult with Health Professionals:** Before starting any new exercise regimen, especially after heart surgery or a heart event, it is crucial to seek advice from health professionals like your physician or cardiac rehabilitation team.
- **Aerobic Exercise:** Engage in aerobic exercises like walking, cycling, or swimming to improve heart and circulatory system function. Encourage a minimum of 150 minutes of aerobic exercise per week at a moderate intensity.
- **Strength Training:** Incorporate resistance training or weightlifting to enhance cardiovascular health and muscle strength. Appropriate technique and the assistance of a trainer can be advantageous.
- **Flexibility and Balance Exercises:** Include stretching, yoga, or balance exercises in your routine to reduce stress and enhance overall heart health. Yoga, in particular, offers various benefits like lowering blood pressure and improving flexibility
- **Interval Training:** Consider interval training for short, intense workouts that benefit lung and heart health. Effective and time-efficient, this form of exercise can enhance cardiovascular fitness.
- **Walking:** Brisk walking is a low-impact exercise that can significantly benefit heart health. It is accessible, gentle on the body, and can be done almost anywhere
- **Swimming:** Swimming is a full-body workout that is gentle on the joints but provides excellent cardiovascular benefits. It helps strengthen the heart and lower blood pressure
- **Personalization and Monitoring:** Tailor your exercise routine based on your fitness level, condition, and advice from healthcare providers. Monitor your heart rate during exercise to ensure you are working out at an appropriate intensity level.

II. LITERATURE REVIEW

Taylor J. et.al. (2021) [28] Numerous meta-analyses have generated debate regarding the effectiveness of exercise-based CR in reducing cardiovascular and all-cause mortality. A recurring theme in these meta-analyses is the heterogeneity and/or absence of specificity regarding the exercise prescription methodology in CR programmes. At this time, there is a lack of global agreement concerning the optimal exercise regimen for CR; nationwide recommendations for exercise intensity vary from light-moderate to moderate to moderate-vigorous. An essential determinant in assessing the efficacy of cardiorespiratory fitness and exercise capacity optimisation is peak oxygen utilisation (VO2peak). This is due to the fact that VO2peak serves as a reliable prognostic indicator of mortality in individuals afflicted with coronary heart disease and heart failure.

Izquierdo, M. et.al. (2021) [29] described that ageing was a common, omnipresent, and unavoidable process in human life. It diminishes all physiological functions in a continuous manner. A sedentary lifestyle and structured exercise (PA and PA, respectively) are two significant ageing phenotypes that differ in the ways in which they are shaped by life circumstances, experiences, and behaviours. The decline in cardiorespiratory fitness and muscular function that occurs with age and sedentary behaviour may impede the ability to perform daily activities independently. Muscle and aerobic capacity changes associated with ageing are substantially mitigated by adequate physical activity or PA. Furthermore, both structured physical activity and regular physical activity play a substantial role in mitigating mortality rates and averting various chronic ailments, including but not limited to stroke, diabetes, obesity, osteoporosis, and obesity. Additionally, they improve mental health, mobility, and quality of life. Cognitive functioning and indicators of infirmity (low body mass, strength, mobility, PA level, energy) are significantly enhanced through exercise intervention programmes, thereby optimising the functional capacity of older individuals. Exercise functions as a therapeutic agent under specific pathological conditions, in accordance with the principle that the aetiology of a disease must be identified prior to administering an evidence-based treatment dosage with the intention of curing or alleviating the malady.

Ghanemi, A. et,al. (2021) [30] studied about the various health advantages of exercise as well as its therapeutic uses, it is now recommended for many pathological illnesses. It has been demonstrated that physical activity elevates the transcription of the secreted protein acidic and cysteine-rich gene (SPARC), suggesting that SPARC functions as a biological mediator of exercise. We thus propose to apply this characteristic to personalised treatment. To do this, prescribe an exercise programme whose pattern (length, intensity, etc.) matches the best possible SPARC/Sparc expression. This strategy is anticipated to maximise exercise therapy for both therapeutic and preventative purposes. Measuring the expression of Sparc in response to exercise might be a useful molecular tool for researchers looking to better optimise their choice of exercise animal models.

Dandanell, S. et.al. (2017) [31] In order to ascertain maximal fat oxidation (MFO) and the exercise intensity that induces MFO (Fat_{Max}) in both normal-weight and obese individuals, graded exercise tests indicate that indirect calorimetry is commonly utilised. On the contrary, there is currently no established validated protocol concerning rotund individuals. Developing a graded exercise protocol for assessing FatMax in obese individuals and establishing validity and inter-method reliability were the primary objectives of this study. A range of exercise intensities was utilised to evaluate fatty oxidation in 16 participants (age: 28 (26-29) years, BMI: 36 (35-38) kg m-2 (95%CI) via a cycle ergometer. The graded exercise protocol was validated using FatMax, as opposed to the brief continuous exercise (SCE) protocol. Fat_{Max} was calculated by dividing fat oxidation at rest by fat oxidation during a 10-minute continuous exercise period at 35%, 50%, and 65% of maximal oxygen uptake (VO2max). The Pearson and intraclass correlation coefficients were 0.75 and 0.72, respectively, and the within-subject CV between the protocols was 5% (3–7%). (12 to 7) (Limits of Agreement) An $VO2_{max}$ bias of -3% was exposed by a Bland Altman plot. The phase change electrode (SCE) and graded protocols achieved FatMax at 42% (40-44) and 45% (43-47) of VO2max, respectively, suggesting a potential systematic distinction (p=0.06).

III. RESEARCH METHODOLOGY

3.1 Study Design

In the context of stroke patients, a randomised controlled trial was conducted to assess the efficacy of two distinct rehabilitation methodologies. Group A was allocated to a rehabilitation protocol tailored specifically for strokes, whereas Group B received a combined intervention comprising individualised cardiac rehabilitation and stroke rehabilitation. Single concealment was utilised to the greatest extent possible, taking into account the characteristics of the interventions. While full anonymity for participants, clinicians, and evaluators was not feasible due to the diverse rehabilitation approaches employed, every effort was made to reduce the likelihood of any possible biases. In order to mitigate selection bias, the allocation of groups was postponed until the completion of baseline assessments. In order to reduce the impact of measurement bias, the assessors responsible for collecting outcome data were not provided with information regarding the group assignment.

3.2 Sample Size Calculation

The determination of the sample size for this inquiry was executed utilising G*Power (version 3.1.9.4). To investigate the primary effects and interactions between two groups utilising two repeated measures that pertain to our dependent measures of interest, we conducted an a priori power analysis for a repeated-measures analysis of variance with a significance level of 0.05 ($\alpha = 80\%$) in order to identify a moderate effect($\eta 2p = 0.05$). The power analysis revealed that in order to attain the intended statistical power, a sample size of 34 participants would be necessary. With a sample size of 38 participants, the study was commenced, however, in consideration of an approximate 10% attrition rate. The study endeavours to guarantee sufficient data for analysis, notwithstanding the possibility of participant attrition during its duration, by account for the potential withdrawal rate and commencing with a marginally larger sample size.

3.3 Sampling Technique

To ascertain participants for this investigation, computerised random sampling was employed. The procedure entailed the utilisation of computer software to produce arbitrary sequences or numbers, which were subsequently employed to ascertain the participants' allocation to Group A or Group B. By providing a method for selecting participants that is both highly systematic and unbiased, computerised random sampling contributes to the methodological rigour of the study and reduces the likelihood of potential biases in group assignment.

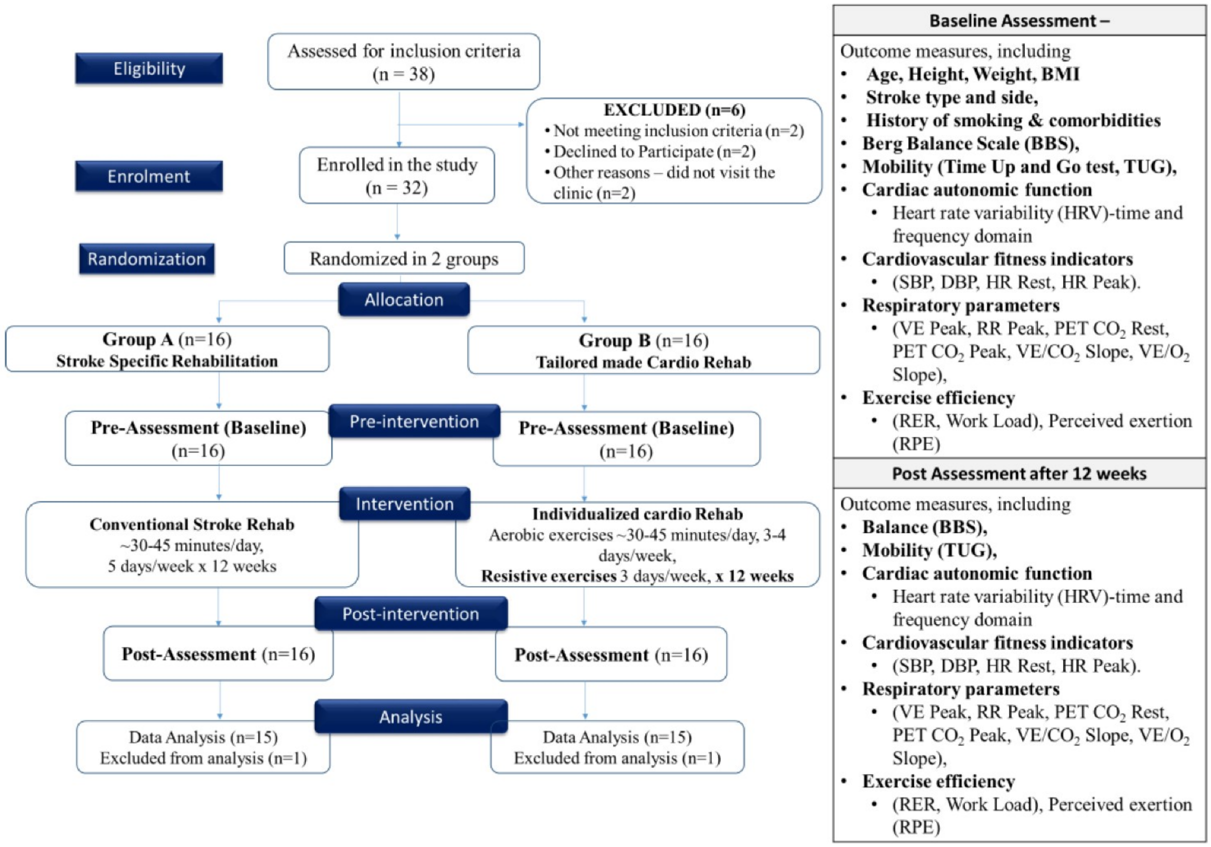


Figure 2. Consort diagram and study flowchart.

Aerobic training lasted five days per week and involved maintaining an intensity of 60 to 80 percent of heart rate reserve (HRR). Furthermore, the predetermined intensity of the exercise, as measured by the rating of perceived exertion (RPE) scale, was understated by 12 to 14 percent on a consistent basis. Throughout the course of the programme, careful attention was paid to active heart rate monitoring. Immediately cease aerobic activity when it exceeded 60–65% of maximal heart rate (HR max). Aerobic exercise sessions were extended in duration from 30 to 45 minutes. Exercise intensity was monitored utilising post-exercise HR and RPE measurements acquired at the conclusion of the session. The weekly mean training HR was calculated by utilising the final HR recordings from the entire session. Each individual was provided with a customised exercise modality. Treadmill exercise was recommended for patients who were able to walk for an adequate duration and speed to attain aerobic benefits. The programme additionally integrated upright and semi-recumbent cycle ergometers[32]. Interval training was also provided to patients who encountered difficulties maintaining a rapid walking or cycling speed for prolonged periods. The exercise regimen comprised brief bursts of vigorous activity followed by extended periods of restorative exercise. Over the variety of exercises conducted, the overall duration of the workouts was given precedence.

An resistance-training regimen was executed, with non-paretic limbs subjected to an initial weight burden of 60% of the one-repetition maximum and paretic limbs bearing a rating of 11–14%. Seven to ten exercises for the upper and lower body comprised this regimen. The exercise was initiated by the participants with ten repetitions, which were progressively increased to fifteen repetitions before the weight increase was implemented. A variety of resistance equipment, including dumbbells, resistance bands, body weight, and weight machines, was utilised. The instructional programme was devised in accordance with individual assessments of hypertonicity, range of motion, balance impairment, and functional abilities. The daily exercise regimen was maintained within the time range of 60 to 75 minutes, with a 20-minute interval separating stroke-specific exercises from cardiac rehabilitation-focused exercises.

3.4 Data Collection and Analysis

The statistical analysis was conducted using SPSS Version 22. Prior to performing parametric tests, we assessed the normality assumption using the Shapiro–Wilk test. Subsequent assessments were carried out for an equivalent duration of time after the exercise-based cardiac rehabilitation programme concluded, or for the control group. To investigate the association between two groups, an independent t-test was employed; for intra-group analysis, a paired t-test was utilised. A 95% confidence interval and a significance level of $p < 0.05$ were employed. Descriptive statistics were utilised by the researchers to calculate and display the mean and standard deviation of the participants in both Group A and Group B.

IV. RESULTS

A thorough evaluation of demographic and medical characteristics was performed in this research endeavour involving stroke patients who were divided into two distinct cohorts: Group A (n = 16; 13 males (80%) and 3 females (22%)) and Group B (n = 16; 13 males (87.7%) and 3 females (13.3%). The mean ages of both groups were comparable (Group A: 59.63 ± 2.72 years; Group B: 60.40 ± 3.20 years; t = −0.74, p = 0.47). In terms of height (Group A: 1.47 ± 0.44 m; Group B: 1.45 ± 0.43 m, t = 1.22, p = 0.23), weight (Group A: 65.20 ± 9.72 kg; Group B: 64.80 ± 10.21 kg, t = 0.11, p = 0.91), and body mass index (BMI), comparable findings were observed. An examination of the distribution of stroke types revealed that 73.3% of Group B and 86.7% of Group A had ischemic strokes ($\chi2$ = 0.83, p = 0.36), with no statistically significant differences observed. Similar results were observed with regard to the direction of the stroke; Group A accounted for 73.3% left-sided strokes, while Group B accounted for 80.0% right-sided strokes ($\chi2$ = 0.19, p = 0.67). Significantly, a divergence in smoking behaviours was observed, with 93.3% of Group B members being smokers compared to 66.7% in Group A ($\chi2$ = 3.33, p = 0.17); however, this difference did not reach statistical significance. Group A had a hypertension rate of 66.7%, while Group B had a rate of 73.3% ($\chi2$ = 0.16, p = 0.69), without any statistically significant difference. Furthermore, the incidence of diabetes was found to be 93.3% in Group A and 80.0% in Group B ($\chi2$ = 1.15, p = 0.28), although these figures did not reach statistical significance. Similarly, cardiac failure was observed in 73.3% of Group B and 80.0% of Group A ($\chi2$ = 0.19, p = 0.67), indicating that there was no statistically significant difference between the two cohorts. The insights gained from these results regarding the initial attributes of the participants in our study (Table 1) are of great value.

Table 1. Demographic data of participants in Group A and Group B.

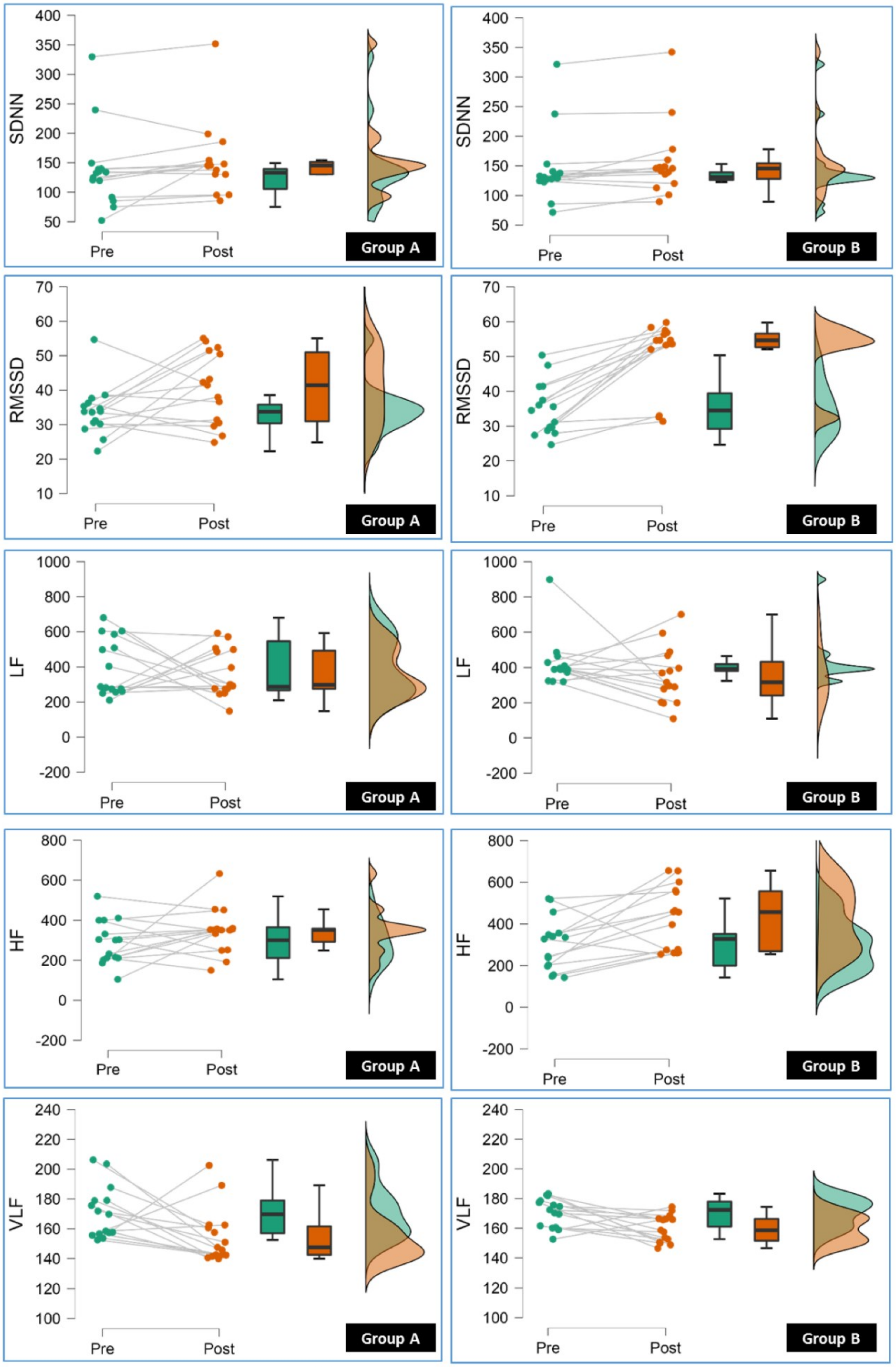
Variable	**Group A**	**Group B**	**χ^2 (Chi-Square)/ t Value**	***p* Value**
Age	60.60 ± 4.72	60.40 ± 3.20	−0.74	0.49
Height	1.57 ± 0.54	1.47 ± 0.43	1.22	0.25
Weight	64.20 ± 9.72	64.81 ± 10.21	0.11	0.93
BMI	32.84 ± 1.79	30.63 ± 4.12	0.19	0.87

By conducting an independent t-test analysis to compare Group A and Group B, we evaluated a range of balance and mobility-related measures. With regard to the BBS, there was an absence of substantial disparity between the two groups in terms of pre-intervention and post-intervention scores (Group A: 40.67 ± 5.79, Group B: 38.13 ± 2.45; t = 1.10, p = 0.28; Group B: 44.73 ± 3.69; t = −0.76, p = 0.66). In a similar vein, the pre-intervention scores for the TUG did not differ significantly between groups (Group A: 26.93 ± 3.06; Group B: 25.93 ± 2.05; t = 1.05, p = 0.40). With a mean difference of 2.69 seconds (95% CI: 0.67–5.46), post-intervention TUG scores for Group B (20.53 ± 4.04; t = 2.62, p = 0.01) exhibited a substantial improvement compared to Group A (23.60 ± 3.36). In order to analyse particular variables within each group prior to and subsequent to the intervention, paired t-tests were employed. Group A's BBS scores exhibited a negligible fluctuation between before and after the intervention. Specifically, their scores were 39.67 ± 4.79 and 51.73 ± 3.56 (t = −1.20, p = 0.25), suggesting a marginal improvement of 2.07. On the other hand, Group B demonstrated a significant enhancement in their BBS scores subsequent to the intervention, as evidenced by a change in scores from 38.13 ± 2.45 to 42.73 ± 3.69 (t = −3.83, p = 0.002). This signifies a significant rise in scores amounting to 4.60. Following the intervention, there was no discernible improvement in the TUG scores of Group A. The durations decreased from 26.93 ± 3.06 to 23.60 ± 3.36 (t = 36.46, p = 0.67). This represents a significant decrease in time by 3.33. In a similar vein, Group B demonstrated a noteworthy improvement in TUG scores, as evidenced by a substantial reduction in completion time of 20.53 ± 3.04 (t = 8.28, p < 0.001) compared to the 25.93 ± 2.05 time required by Group A.

Table 2: Independent t-test for comparative analysis of pre and post data between groups to assess variations in cardiovascular and autonomic nervous system parameters.

Variable		Group A Mean ± SD	Group B Mean ± SD	t-Value	p-Value	95% CI (Lower–Upper)
Mean NN	Pre	821.83 ± 62.13	836.72 ± 46.82	−0.77	0.45	−52.40–25.62
	Post	849.69 ± 52.72	912.82 ± 72.95	−3.08	0.01	−118.73–−23.54
Resting HR	Pre	76.27 ± 4.44	77.33 ± 6.31	−1.06	0.31	−6.18–2.01
	Post	72.47 ± 7.07	70.15 ± 6.46	0.94	0.36	−2.71–7.38
SDNN	Pre	72.47 ± 7.07	145.08 ± 60.40	−0.33	0.77	−55.12–40.88
	Post	153.17 ± 62.84	156.55 ± 62.17	−0.15	0.88	−50.14–43.37
RMSSD	Pre	33.78 ± 7.26	34.93 ± 7.59	−0.41	0.68	−6.67–4.44
	Post	40.56 ± 10.46	50.73 ± 9.80	−2.78	0.01	−17.87–−2.71
pNN50	Pre	42.55 ± 6.49	42.07 ± 5.05	0.22	0.83	−3.80–4.82
	Post	43.98 ± 6.19	44.69 ± 5.20	−0.33	0.75	−4.97–3.59
LF	Pre	398.73 ± 163.33	425.19 ± 139.34	−0.48	0.64	−140.01–87.09
	Post	361.03 ± 136.36	352.56 ± 159.72	0.16	0.88	−102.60–119.55
HF	Pre	288.85 ± 109.40	301.94 ± 127.05	−0.30	0.76	−101.47–75.59
	Post	346.13 ± 115.41	426.07 ± 153.52	−1.61	0.12	−181.72–21.64
VLF	Pre	170.98 ± 17.60	170.67 ± 9.75	0.06	0.95	−10.44–10.95
	Post	155.27 ± 18.56	159.85 ± 9.12	−0.86	0.40	−15.52–6.36
TP	Pre	903.13 ± 39.93	911.90 ± 44.54	−0.57	0.57	−40.41–22.87
	Post	915.21 ± 59.93	921.43 ± 70.68	−0.26	0.80	−55.25–42.77
LF/HF	Pre	1.56 ± 0.53	1.73 ± 1.09	−0.87	0.39	−0.91–0.37
	Post	1.10 ± 0.40	0.90 ± 0.43	1.27	0.21	−0.12–0.51
nLF	Pre	44.20 ± 18.06	47.05 ± 17.70	−0.43	0.67	−16.18–10.56
	Post	39.89 ± 16.12	38.57 ± 17.50	0.21	0.83	−11.27–13.90
nHF	Pre	32.08 ± 12.37	33.12 ± 13.84	−0.22	0.83	−10.87–8.78
	Post	38.02 ± 12.78	46.91 ± 18.70	−1.52	0.14	−20.87–3.09

Table 2 presents the results of an independent *t*-test comparing the effects of stroke-specific rehab in Group A and individualized cardio rehab in Group B. Group B exhibited significantly improved Post-Mean NN ($p = 0.01$) and Post RMSSD ($p = 0.01$) compared to Group A, indicating enhanced heart rate variability and parasympathetic nervous system activity following the intervention. However, there were no significant differences between the groups in Pre Mean NN, Resting Pre HR, Resting Post HR, Pre SDNN, Post SDNN, Pre NN50, Pre LF, Post LF, Pre HF, Pre VLF, Post VLF, Pre TP, Post TP, Pre LF/HF, Pre nLF, and Post nLF (all $p > 0.05$).



(A)

Figure 2. (A): The line, box, and density plots from repeated measure

The aforementioned raincloud display utilised analysis of variance (ANOVA) to examine SDNN (Standard Deviation of NN intervals), RMSSD (Root Mean Square of Successive Differences), VLF (Very Low Frequency), HF (High Frequency), and LF (Low Frequency) values pertaining to individual participants in Group A and Group B. (B): Individual participant density, box, and line plots derived from repeated-amount to measure were subjected to analysis of variance (ANOVA) in this raincloud display. The variables under consideration were LF/HF (Normalised Low Frequency), nHF (Normalised High Frequency), and nLF (Normalised Low Frequency) pre-post measurements for Group A and Group B. Elevated root mean square of successive differences (RMSSD) and NN intervals (SDNN) are both indicative of improved autonomic regulation and cardiac adaptability to stress, and are associated with individualised cardiorehabilitation for stroke patients. Critical of cardiac adaptability is recovery of heart rate, which refers to the speed at which the heart rate returns to normal after exercise. A possible consequence of consistent physical activity during cardiac rehabilitation is an increase in SDNN and RMSSD, which are indicators of a restored heart rate. By means of a personalised rehabilitation regimen that incorporates a progressive sequence of exercises, individuals are able to gradually adjust to increasing levels of physical activity. The improvement of HRV parameters and adaptation of the cardiovascular system may be attributable to this controlled approach [33]. Physical activity can have a beneficial impact on autonomic function and aid in the acceleration of HRR recovery following physical exertion [34]. Analysis of variance (ANOVA) was employed in the previously mentioned raincloud display to investigate the SDNN (Standard Deviation of NN intervals), RMSSD (Root Mean Square of Successive Differences), VLF (Very Low Frequency), HF (High Frequency), and LF (Low Frequency) values associated with specific participants in Group A and Group B. (B): The raincloud display underwent analysis of variance (ANOVA) on individual participant density, box, and line plots that were obtained from repeated-amount to measure data. The variables being examined were pre-post measurements of LF/HF (Normalised Low Frequency), nHF (Normalised High Frequency), and nLF (Normalised Low Frequency) for Group A and Group B. Individualised cardiorehabilitation for stroke patients is associated with elevated root mean square of successive differences (RMSSD) and NN intervals (SDNN), both of which are indicative of enhanced cardiac adaptability to stress and improved autonomic regulation. Recovery of heart rate, denoting the velocity at which the heart rate reverts to its baseline level subsequent to physical exertion, is a pivotal indicator of cardiac adaptability. SDNN and RMSSD, which serve as indicators of a reinstated heart rate, may experience an increase as a result of regular physical activity during cardiac rehabilitation.

IV. CONCLUSION

In conclusion, the prospective benefits of individualised cardiac rehabilitation programmes for stroke patients are highlighted in this study. Personalised programmes designed to cater to the distinct requirements of stroke survivors have demonstrated noteworthy advancements in autonomic regulation, mobility, balance, and exercise efficiency. This is evidenced by decreased respiratory exchange ratios (RER), decreased ratings of perceived exertion (RPE), increased heart rate variability (HRV), and enhanced ventilatory efficiency. The results of this study emphasise the significance of personalised rehabilitation strategies in maximising the recuperation process, enhancing cardiovascular well-being, and enhancing overall welfare among individuals who have survived stroke. As demonstrated by the raincloud display's analysis of SDNN, RMSSD, LF, HF, VLF, LF/HF ratio, nLF, and nHF measurements for individual participants in Group A and Group B, individualised cardiorehabilitation for stroke patients is crucial. The findings suggest that such rehabilitation programmes are linked to increased RMSSD and SDNN, indicating enhanced autonomic control and tolerance to cardiac duress. Heart rate recovery (HRR) enhancements provide additional substantiation for the advantageous impacts of consistent exercise accompanied by individualised exercise regimens.

Additionally, as it facilitates cardiovascular system adaptability and improves autonomic function, the study emphasises the significance of a gradual and regulated approach to physical exercise within rehabilitation regimens. It is critical to recognise that individual responses to rehabilitation will vary, despite the fact that elevated SDNN and RMSSD are generally considered favourable indicators of enhanced autonomic regulation. Moreover, the increase in VLF power observed after rehabilitation suggests possible improvements in thermoregulation and downregulation of the renin-angiotensin-aldosterone system, both of which could positively influence cardiovascular health and blood pressure regulation. Moreover, alterations in the LF/HF ratio in the positive direction indicate enhanced autonomic balance and stress reactivity. Personalised cardiovascular rehabilitation exercises, according to the combined data, significantly improve the cardiovascular health of stroke patients by positively influencing a number of physiological parameters, such as sympathetic–parasympathetic balance, thermoregulation, cardiac autonomic function, and activity of the renin–angiotensin–

aldosterone system. These results emphasise the significance of customised rehabilitation plans for improving stroke patients' outcomes and the many advantages of exercise as medicine in cardiovascular care.

REFERENCES

[1] Rizvi, M.R.; Ali, N.I.; Ahmed, A.I.; Adam, R.A.; Elgak, S.N. Knowledge, Attitude, and Practice of Stroke and Its Risk Factors and Warning Signals among the Students of the College of Applied Medicine at Majmaah University, Saudi Arabia. *Biomedicine* **2023**, *13*, 326–332.

[2] Benjamin, E.J.; Muntner, P.; Alonso, A.; Bittencourt, M.S.; Callaway, C.W.; Carson, A.P.; Chamberlain, A.M.; Chang, A.R.; Cheng, S.; Das, S.R.; et al. Heart disease and stroke statistics—2019 update: A report from the American Heart Association. *Circulation* **2019**, *139*, e56–e528.

[3] Katan, M.; Luft, A. Global burden of stroke. *Semin. Neurol.* **2018**, *38*, 208–211.

[4] Billinger, S.A.; Coughenour, E.; MacKay-Lyons, M.J.; Ivey, F.M. Reduced cardiorespiratory fitness after stroke: Biological consequences and exercise-induced adaptations. *Stroke Res. Treat.* **2012**, *2012*, 959120.

[5] Esterov, D.; Greenwald, B.D. Autonomic dysfunction after mild traumatic brain injury. *Brain Sci.* **2017**, *7*, 100.

[6] Chaitra, B.; Narhare, P.; Puranik, N.; Maitri, V. Moderate intensity aerobics training improves pulmonary function in young Indian men. *Biomed. Res.* **2012**, *23*, 231–233.

[7] Hoegg, S.; Elsner, B.; Saunders, D.H.; Wijck, F.; Mehrholz, J. Resistive strength training for arm rehabilitation after stroke. *Cochrane Database Syst. Rev.* **2021**, *2021*, CD014279.

[8] Taylor, R.S.; Walker, S.; Smart, N.A.; Piepoli, M.F.; Warren, F.C.; Ciani, O.; O'Connor, C.; Whellan, D.; Keteyian, S.J.; Coats, A.; et al. Impact of exercise-based cardiac rehabilitation in patients with heart failure (ExTraMATCH II) on mortality and hospitalisation: An individual patient data meta-analysis of randomised trials. *Eur. J. Heart Fail.* **2018**, *20*, 1735–1743.

[9] Billinger, S.A.; Arena, R.; Bernhardt, J.; Eng, J.J.; Franklin, B.A.; Johnson, C.M.; MacKay-Lyons, M.; Macko, R.F.; Mead, G.E.; Roth, E.J.; et al. Physical activity and exercise recommendations for stroke survivors: A statement for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke* **2014**, *45*, 2532–2553.

[10] Regan, E.W.; Handlery, R.; Stewart, J.C.; Pearson, J.L.; Wilcox, S.; Fritz, S. Integrating Survivors of Stroke into Exercise-Based Cardiac Rehabilitation Improves Endurance and Functional Strength. *J. Am. Heart Assoc.* **2021**, *10*, e017907.

[11] Sun, X.; Gao, Q.; Dou, H.; Tang, S. Which is better in the rehabilitation of stroke patients, core stability exercises or conventional exercises? *J. Phys. Ther. Sci.* **2016**, *28*, 1131–1133.

[12] Shahid, J.; Kashif, A.; Shahid, M.K. A Comprehensive Review of Physical Therapy Interventions for Stroke Rehabilitation: Impairment-Based Approaches and Functional Goals. *Brain Sci.* **2023**, *13*, 717.

[13] Hebert, D.; Lindsay, M.P.; McIntyre, A.; Kirton, A.; Rumney, P.G.; Bagg, S.; Bayley, M.; Dowlatshahi, D.; Dukelow, S.; Garnhum, M.; et al. Canadian stroke best practice recommendations: Stroke rehabilitation practice guidelines, update 2015. *Int. J. Stroke* **2016**, *11*, 459–484.

[14] Rodgers, H.; Price, C. Stroke unit care, inpatient rehabilitation and early supported discharge. *Clin. Med.* **2017**, *17*, 173.

[15] Price, K.J.; Gordon, B.A.; Bird, S.R.; Benson, A.C. A review of guidelines for cardiac rehabilitation exercise programmes: Is there an international consensus? *Eur. J. Prev. Cardiol.* **2016**, *23*, 1715–1733.

[16] Warburton, D.E.; Bredin, S.S. Health benefits of physical activity: A systematic review of current systematic reviews. *Curr. Opin. Cardiol.* **2017**, *32*, 541–556.

[17] Aftyka, J.; Staszewski, J.; Dębiec, A.; Pogoda-Wesołowska, A.; Żebrowski, J. Heart rate variability as a predictor of stroke course, functional outcome, and medical complications: A systematic review. *Front. Physiol.* **2023**, *14*, 1115164.

[18] Chen, Z.; Venkat, P.; Seyfried, D.; Chopp, M.; Yan, T.; Chen, J. Brain–heart interaction: Cardiac complications after stroke. *Circ. Res.* **2017**, *121*, 451–468.

[19] Huang, C.-Y.; Lin, G.-H.; Huang, Y.-J.; Song, C.-Y.; Lee, Y.-C.; How, M.-J.; Chen, Y.-M.; Hsueh, I.-P.; Chen, M.-H.; Hsieh, C.-L. Improving the utility of the Brunnstrom recovery stages in patients with stroke: Validation and quantification. *Medicine* **2016**, *95*, e4508.

[20] Keller, K.; Geyer, M.; Muenzel, T.; Ostad, M.A. Gender-differences in prevalence and outcome of ischemic stroke and promoting factors of atrial thrombi. *Artery Res.* **2018**, *22*, 68–78.

[21] Hansen D, Abreu A, Ambrosetti M, Cornelissen V, Gevaert A, Kemps H, et al. Exercise intensity assessment and prescription in cardiovascular rehabilitation and beyond: why and how: a position statement from the secondary prevention and rehabilitation section of the european association of preventive cardiology. Eur J Prev Cardiol. (2021). 2:zwab007. doi: 10.1093/eurjpc/zwab007

[22] Rauch B, Davos CH, Doherty P, Saure D, Metzendorf M-I, Salzwedel A, et al. The prognostic effect of cardiac rehabilitation in the era of acute revascularisation and statin therapy: a systematic review and meta-analysis of randomized and non-randomized studies - The Cardiac Rehabilitation Outcome Study (CROS). Eur J Prev Cardiol. (2016) 23:1914– 39. doi: 10.1177/2047487316671181

[23] Salzwedel A, Jensen K, Rauch B, Doherty P, Metzendorf MI, Hackbusch M, et al. Effectiveness of comprehensive cardiac rehabilitation in coronary artery disease patients treated according to contemporary evidence based medicine: update of the cardiac rehabilitation outcome study (CROS-II). Eur J Prev Cardiol. (2020) 27:1756–74. doi: 10.1177/2047487320905719

[24] Heran BS, Chen JM, Ebrahim S, Moxham T, Oldridge N, Rees K, et al. Exercise-based cardiac rehabilitation for coronary heart disease. Cochrane Database Syst Rev. (2011). 6:CD001800. doi: 10.1002/14651858.CD001800.pub2

[25] Taylor RS, Brown A, Ebrahim S, Jolliffe J, Noorani H, Rees K, et al. Exercisebased rehabilitation for patients with coronary heart disease: systematic review and meta-analysis of randomized controlled trials. Am J Med. (2004) 116:682–92. doi: 10.1016/j.amjmed.2004.01.009

[26] Long L, Mordi IR, Bridges C, Sagar VA, Davies EJ, Coats AJ, et al. Exercisebased cardiac rehabilitation for adults with heart failure. Cochrane Database Syst Rev. (2019) 1:Cd003331. doi: 10.1002/14651858.CD003331.pub5

[27] West RR, Jones DA, Henderson AH. Rehabilitation after myocardial infarction trial (RAMIT): multi-centre randomised controlled trial of comprehensive cardiac rehabilitation in patients following acute myocardial infarction. Heart. (2012) 98:637–44. doi: 10.1136/heartjnl-2011-300302

[28] Taylor, J. L., Bonikowske, A. R., & Olson, T. P. (2021). Optimizing outcomes in cardiac rehabilitation: the importance of exercise intensity. *Frontiers in Cardiovascular Medicine*, *8*, 734278.

[29] Izquierdo, M., Merchant, R. A., Morley, J. E., Anker, S. D., Aprahamian, I., Arai, H., ... & Singh, M. F. (2021). International exercise recommendations in older adults (ICFSR): expert consensus guidelines. *The journal of nutrition, health & aging*, *25*(7), 824-853.

[30] Ghanemi, A., Yoshioka, M., & St-Amand, J. (2021). Measuring exercise-induced secreted protein acidic and rich in cysteine expression as a molecular tool to optimize personalized medicine. *Genes*, *12*(11), 1832.

[31] Dandanell, S., Præst, C. B., Søndergård, S. D., Skovborg, C., Dela, F., Larsen, S., & Helge, J. W. (2017). Determination of the exercise intensity that elicits maximal fat oxidation in individuals with obesity. *Applied Physiology, Nutrition, and Metabolism*, *42*(4), 405-412.

[32] Anderson L, Oldridge N, Thompson DR, Zwisler A-D, Rees K, Martin N, et al. Exercise-based cardiac rehabilitation for coronary heart disease: cochrane systematic review and meta-analysis. J Am Coll Cardiol. (2016) 67:1–12. doi: 10.1016/j.jacc.2015.10.044

[33] Powell R, McGregor G, Ennis S, Kimani PK, Underwood M. Is exercisebased cardiac rehabilitation effective? A systematic review and metaanalysis to re-examine the evidence. BMJ Open. (2018) 8:e019656. doi: 10.1136/bmjopen-2017-019656

[34] Conraads VM, Denollet J, De Maeyer C, Van Craenenbroeck E, Verheyen J, Beckers P. Exercise training as an essential component of cardiac rehabilitation. Heart. (2012) 98:674. doi: 10.1136/heartjnl-2012-301912

[35] Franklin BA. Multifactorial cardiac rehabilitation did not reduce mortality or morbidity after acute myocardial infarction. Ann. Internal Med. (2012) 157:JC1-11. doi: 10.7326/0003-4819-157-2-201207170-02011

[36] Ingle L, Carroll S. Cardiac rehabilitation and exercise training. Heart. (2013) 99:1298. doi: 10.1136/heartjnl-2013-304015

[37] Nichols S, Taylor C, Goodman T, Page R, Kallvikbacka-Bennett A, Nation F, et al. Routine exercise-based cardiac rehabilitation does not increase aerobic fitness: a CARE CR study. Int J Cardiol. (2020) 305:25–34. doi: 10.1016/j.ijcard.2020.01.044