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Comparative Effects of Circuit Training and Resistance Training in Coronary Artery Disease Post-CABG Patients

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Abstract: ***Background**: Coronary artery disease (CAD) remains one of the leading causes of morbidity and mortality worldwide. Coronary artery bypass graft (CABG) surgery is frequently performed to restore myocardial perfusion in patients with advanced CAD. Cardiac rehabilitation, particularly exercise-based rehabilitation, plays a crucial role in improving functional capacity and reducing cardiovascular risk following CABG. Although resistance training and circuit weight training are both used in cardiac rehabilitation programs, evidence comparing their effectiveness in post-CABG patients remains limited. **Objective**: To compare the effects of circuit weight training (CWT) and resistance training (RT) on myocardial oxygen demand and functional capacity in male patients following CABG surgery. **Methods**: A randomized controlled trial was conducted among 34 male patients who were 10 weeks post-CABG surgery and had completed phase II cardiac rehabilitation. Participants were randomly allocated into two groups using a simple randomization lottery method: Group A (Circuit Weight Training, n=17) and Group B (Resistance Training, n=17). Both groups underwent supervised exercise training three times per week for eight weeks. The primary outcome measure was Rate Pressure Product (RPP), calculated from systolic blood pressure and heart rate as an indirect measure of myocardial oxygen demand. Ethical approval was obtained from the Institutional Ethics Committee before study initiation, and all participants provided written informed consent. The trial should be prospectively registered in the Clinical Trials Registry–India (CTRI) and the registration number should be reported. **Results**: Both intervention groups demonstrated statistically significant reductions in RPP following eight weeks of training. Group A improved from 116.18 ± 5.2 to 94.83 ± 5.8 ($p<0.0001$), while Group B improved from 116.41 ± 4.50 to 97.96 ± 5.05 ($p<0.001$). No significant difference was observed between groups at post-intervention assessment ($p=0.0971$). **Conclusion**: Both circuit weight training and resistance training are safe and effective exercise modalities for improving myocardial oxygen demand in low-risk post-CABG patients. No significant superiority of one intervention over the other was observed, suggesting that both can be incorporated into cardiac rehabilitation programs based on patient preference and clinical requirements.*

Keywords: CABG: Coronary Artery Bypass Graft, RPP: Rate Pressure Product, SBP: Systolic Blood Pressure, HR: Heart Rate, 1-RM: One Repetition Maximum, CWT: Circuit Weight Training

1. Introduction

Heart disease is among the causes of morbidity and mortality in the world. The term refers to a number of clinical diagnoses such as myocardial infarction, angina pectoris, heart failure, arrhythmias and dysfunction of the valves. The most common of them is the coronary artery disease (CAD), which is an atherosclerotic constriction of coronary arteries resulting in the insufficient provision of myocardium with blood. [1]

CAD is caused by the partial or total blockage of one or more of the main coronary arteries leading to reduced blood circulation and lack of sufficient oxygen to the heart muscle. This is caused by accumulating changes in the inner lining and wall of the coronary arteries, which are referred to as atherosclerosis. Such alterations are intimal proliferation and thickening, excessive deposition of fatty tissue, fibrous cellular debris and calcium salts to create atherosclerotic plaques. [1]

Advanced coronary atherosclerotic lesions require three essential elements in their disease pathogenesis: (i) Endothelial Injury, in which mechanical trauma is caused by pulsation of coronary arterial pressure and sustained exposure to high cholesterol-carrying lipoproteins are factors that cause endothelial damage, (ii) Lipid Infiltration, in which the white blood cells enter the injured endothelium and deposit lipid, and the macrophages produce growth factors, which promote smooth muscle thickening and (iii) Platelet- Fibrin Deposition in this last stage, the platelet activation of blood clotting system may cause platelet attachment and micro thrombus formation which may result in coronary thrombosis and acute myocardial infarction.

CAD has been diagnosed using electrocardiography (ECG), stress testing, and coronary angiography. Treatment options include percutaneous coronary intervention (PCI), coronary artery bypass graft (CABG) surgery, and medicinal therapy, which includes nitro-glycerine and long-acting nitrates. CABG uses internal mammary artery grafts or saphenous veins to restore enough blood flow past atherosclerotic lesions.[2]

Through safe return to physical activities, cardiac rehabilitation has developed into a multidisciplinary, complex treatment that involves educating patients, training them in customised exercises, changing risk factors, and ensuring their well-being. [3] The definition given by the World Health Organization (WHO) defines cardiac rehabilitation as a combination of activities that should influence the causal factor of the disease and good use of physical, mental and social conditions. [4]

Coronary artery is the most prevalent health issue in populations of the middle age and it has a great influence on lifestyle. Muscular strength and cardiovascular endurance can only be achieved through appropriate cardiac rehabilitation using lifestyle modification and exercise regimes.The circuit training group performed a 10 minute warm-up, consisting of calisthenics and stretching, then exercised in the circuit training room for 20 minutes and

performed a 20 minute walk/jog exercise during each session. [6.] Circuit Weight Stations are for different areas of the body :Arm curl, High pulley, Low pulley, Bench press, Double leg curl , Double leg extension, Bent leg Sit-ups, Hip flexion[6.] Every subject had to go through the all circuit stations for completing one circuit.before going to the circuit patient is taught how to positioned properly for each circuit station and the exercise procedure had been explained to the patient.

Resistance training is a form of exercises using weight.the resistance can be used either in the form of individuals body weight or gravity or friction or by machine. etc..for this study weight cuffs and dumbbells are used as a resistance.For experimental group, resistance training was performed three times per week for 8 weeks. The resistance training program was established on the basis of baseline 1-RM lifts. Patients performed 1-RM testing for six exercises, at the first day of training. Weight training began at 50% of 1-RM and training intensity was gradually increased toward 75% of 1-RM, as tolerated. The six exercises focused on arm, shoulder and leg strength. Resistance training included bench press, arm curls, lateral raise, leg curl, leg extensions and triceps kickback.Patients began resistance training with one set of 10 repetitions, gradually increasing to two and three sets with a 2-min rest in between each set exercise positioning and the exercise process has been explained to the patient before the starting of exercise.

2. Material and Methods

Circuit training process involves that the series of exercises to be done is at moderate levels and repeated frequently. This method places demands on the skeletal muscles and cardiovascular system whereby the trainees are engaged in a set of short-term and moderate weight load and then a break. It appears that circuit training is safe and the changes in aerobic endurance and musculoskeletal fitness are enormous as compared to the exercises of cardiac rehabilitation. [6]

Cardiac rehabilitation is a continuum of care that commences with hospitalization up until community follow-up:
Phase 1 -Inpatient Period: Introducing the first-time assessment and mobilization in the hospital with a lifestyle recommendation.
Phase 2 -Early Post-Discharge: Lifestyle interventions of the multidisciplinary team and total evaluation of the risks.
Phase 3 -Supervised Outpatient Programme: Risk-stratified structured exercise, individualized exercise prescription and psycho-social interventions.
Phase 4 - Long-Term Follow-Up: On-going maintenance of individual goals through the procedure of a clinical observation and psycho-social support.

The types of cardiovascular conditioning exercise include:
Constant Training: Aerobic: constant sub maximal (treadmill, bicycling, walking)
Interval Training: The combination of active recovery in between periods of higher and lower intensity.
Cool Down: Mostly pulse-reducing activities which include stretching and joint mobilization exercises (at least 10-15 minutes)

Resistance Training: This will be done following 4- 6 months of aerobic training and will entail two sessions of 8-10 activities using large body parts. [5]

The resistance training is a form of exercise which involves weight resistance by use of body weight, gravity, friction, machine, springs or elastic structures. They are also known as progressive resistance exercises which were proposed by De Lorme in 1945 and are muscle power and volume restorative by slowly increasing resistance on an equivalent ratio of muscle strength gain. [7] There are four main processes that are based on muscle resistance that consist of; increased poundage, increased leverage, altered speed of movement and increased exercise time.

This randomized clinical trial examined the effects of different exercise training modalities on male patients with coronary artery disease following coronary artery bypass graft (CABG) surgery. The study included 34 male subjects who were 10 weeks post-CABG and had completed normal cardiac rehabilitation pre-training, with ages ranging from 40 to 50 years. Participants were allocated using simple random sampling with a lottery method, and the primary outcome measure was the Rate Pressure Product (RPP), which serves as an indirect measure of myocardial oxygen consumption calculated as systolic blood pressure multiplied by heart rate and divided by 10. This measure is particularly relevant for coronary artery disease patients because angina typically appears at a constant RPP, with most patients experiencing pain at an RPP of 20,000.

Study Design
This study was designed as a parallel-group randomized controlled trial (RCT) comparing the effects of circuit weight training and resistance training in patients following CABG surgery.

Ethical Approval and Trial Registration
The study protocol was reviewed and approved by the Institutional Ethics Committee prior to commencement of participant recruitment. Written informed consent was obtained from all participants before enrollment. As this study was conducted as a randomized controlled trial, prospective registration in the Clinical Trials Registry–India (CTRI) is required. The CTRI registration number and date of registration should be reported in the manuscript.

Study Setting and Participants
The study included 34 male patients aged 40–50 years who were 10 weeks post-CABG surgery and had successfully completed standard cardiac rehabilitation before enrollment. Participants were recruited from the cardiac rehabilitation unit of the Peoples Hospital Bhanpur Bhopal MP.

Inclusion Criteria
- Male patients aged 40–50 years.
- Ten weeks post-CABG surgery. • Completion of routine cardiac rehabilitation program.
- Medically stable and cleared for exercise participation.

Exclusion Criteria

- Female patients because there is a less risk of cardiac failure due to distinct biological, hormonal and lifestyle factors.
- High-risk CABG patients.
- Patients with abnormal hemodynamic responses to exercise.
- History of tachyarrhythmias.
- Hospitalization for heart failure during the previous year.
- Pulmonary, renal, musculoskeletal, or neurological conditions limiting exercise performance.

Randomization

Participants were randomly assigned to either the Circuit Weight Training group (Group A) or Resistance Training group (Group B) using simple randomization through a lottery method. Each participant had an equal probability of being allocated to either intervention group. Randomization was performed by an independent investigator who was not involved in participant assessment or treatment delivery.

Allocation Concealment

To minimize selection bias, allocation concealment was maintained using sequentially numbered, opaque, sealed envelopes (SNOSE). Group assignments were prepared before participant recruitment and opened only after completion of baseline assessment.

Blinding

Due to the nature of exercise interventions, participant and therapist blinding was not feasible. However, outcome assessments were performed by an assessor who was blinded to group allocation. Statistical analysis was conducted using coded data to reduce assessment bias.

Baseline Assessment

Before intervention, all participants underwent an Exercise Tolerance Test (ETT) using the Bruce treadmill protocol. Resting heart rate and systolic blood pressure were recorded. Rate Pressure Product (RPP) was calculated using the formula:

RPP = (Heart Rate × Systolic Blood Pressure)/10

Intervention

Group A: Circuit Weight Training

Participants performed circuit weight training using variable resistance machines. Training sessions were conducted three times per week for eight weeks. Each session consisted of a 10-minute warm-up, circuit exercises involving major upper and lower limb muscle groups, and a 20-minute cool-down period. Participants completed 12–15 repetitions at each station with 30-second exercise and rest intervals.

Group B: Resistance Training

Participants underwent progressive resistance training using dumbbells and weight cuffs. One-repetition maximum (1-RM) testing was performed to determine baseline strength. Training intensity began at 50% of 1-RM and progressed gradually to 75% of 1-RM over the intervention period. Sessions were conducted three times weekly for eight weeks.

Outcome Measure

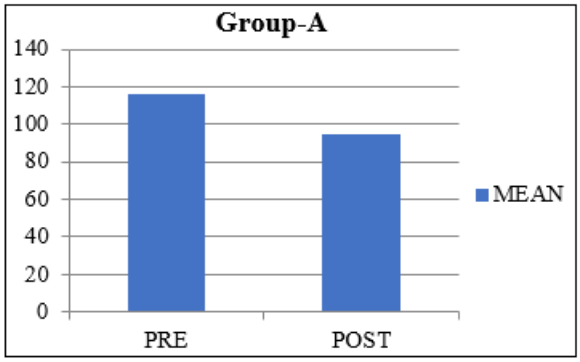
The primary outcome measure was Rate Pressure Product (RPP), which reflects myocardial oxygen demand and cardiac workload. Measurements were recorded at baseline and after completion of the eight-week intervention.

3. Results

Group A (Circuit Training) - RPP Data

Table 1: Pre and post RPP means for Group A were 116.18 and 94.83 respectively. Using paired t-test analysis, the t-value was 12.30 with p<0.0001, indicating extremely significant improvement in RPP following circuit training.

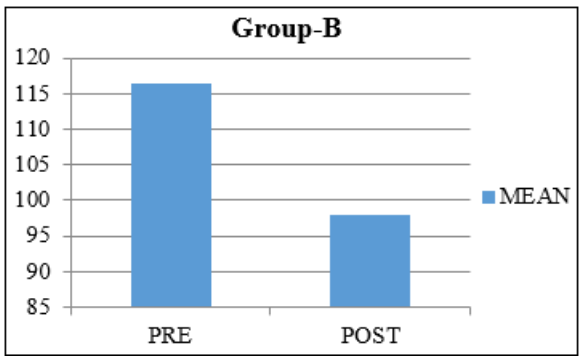
Group -A	Mean	Standard Deviation	Significance
Pre	116.18	5.2	P<0.001
Post	94.83	5.8	t=12.30



Group B (Resistance Training) - RPP Data

Table 2: Pre and post RPP means for Group B were 116.41 and 97.96 respectively. Paired t-test analysis yielded a t-value of 12.44 with p<0.001, indicating extremely significant improvement following resistance training.

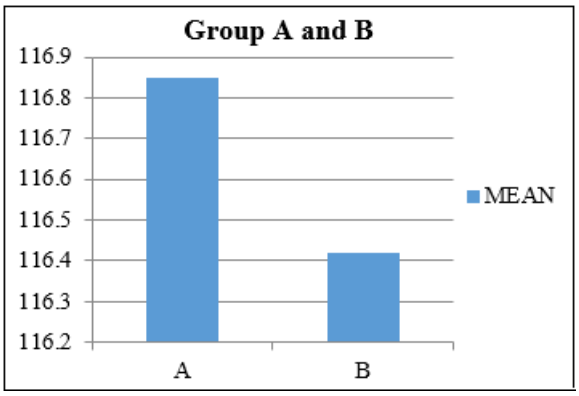
Group -B	Mean	Standard Deviation	Significance
Pre	116.41	4.50	P<0.001
Post	97.96	5.05	t=12.44



Pre-Intervention Between-Group Comparison

Table 3: Pre-intervention RPP comparison using unpaired t-test showed no significant difference between groups (p=0.80, t=0.26), confirming baseline equivalence

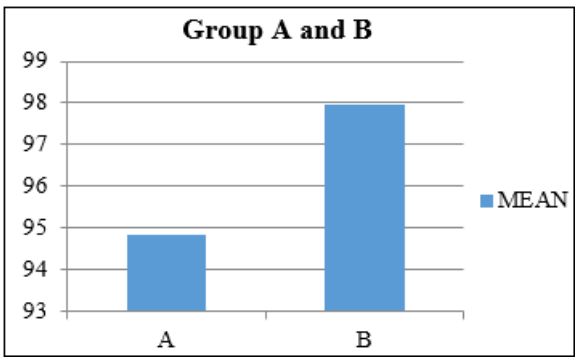
Post	Mean	Standard Deviation	Significance
A	116.85	5.30	P=0.80
B	116.42	4.50	t=0.26



Post-Intervention Between-Group Comparison

Table 4: Post-intervention RPP comparison using unpaired t-test revealed no significant difference between circuit and resistance training groups (p=0.0971, t=1.71), indicating equivalent effectiveness of both modalities

Post	Mean	Standard Deviation	Significance
A	94.83	5.61	P=0.0971
B	97.96	5.056	t=1.71



These findings align with research showing that exercise-based cardiac rehabilitation significantly improves cardiovascular function and reduces cardiac workload. The comparable effectiveness of circuit training and resistance training provides clinicians with flexibility in exercise prescription for cardiac rehabilitation programs.

4. Discussion

It was done as a result of the current study to establish the result of the resistance training and circuit training on the functional capacities and skeletal muscle strength of male patients with CABG. 34 patients with CABG were randomly selected to complete the study and reported the results of the 8 weeks training intervention period as follows: There are no major differences in the effects of circuit and resistance training. Aboriginal hemodynamic response to exercise may be an indicator of greater risk of CAD, even in the presence of no signs and symptoms of ischemia suggesting the same. Both SBP and HR are the remarkable variables which characterize the changes in myocardial oxygen consumption during exercise and rest. During exercise, SBP and RPP increase with an increase of the work load on the heart in order to provide the working myocardium with enough blood. Exercise increases RPP in a steady manner. The imbalance between the supply and demand of oxygen is the cause of angina, this occurs due to the fact that more work of myocardium is needed to be reached to a critical level; this level is established in each patient. RPP is used to measure myocardial work. The average values of RPP are 20- 35 mm Hg x beats/ min x 10-3. RPP value greater than 25 mm Hg x beats/min x 1/10-3 is not usual among most patients with severe Ischemic Heart Disease. [2]. The rate pressure product of greater than 22,000 that has been mentioned in the research is normally associated with angina and heart ischemia. It is established that specific RPP is observed which is the onset of angina in a particular patient with CAD. Most of the patients would complain continuous pain at a constant RPP of 20,000 The optimum RPP is the actual representation of myocardial oxygen demand and myocardial work load. The higher the RPP, the higher will be the MVO2. The increased RPP is associated with the fact that the perfusion of the coronary is more adequate. The high RPP without symptoms or signs of severe ischemia is the indication of the presence of adequate left ventricular functions, the low PRPP values is the sign of a severe limitation of coronary perfusion as well as the decreased LV functioning is the factor of angina occurrence. Maximum RPP is said to lie between 10th percentile value of 25,000 and 90th percentile value of 40,000. [10]. RPP of above 22 is normally attributed to Myocardial Ischemia and Angina. Since exercise is type and muscle group specific, it was projected that there would be an increase in strength of muscle strength in both upper and lower extremities. That training on resistance and circuit increased muscle strength of extremities. The use of weight-lifting exercises has not been extensively directed at the cardiac patients. However, the studies indicate that carrying weight and lifting is a rather safe activity among selected patients in the case of its occurring after the Myocardial Infarction. The fact is that in their employment, as well as during their leisure time, cardiac patients need to gain or improve upper body strength as it would lead to improved prognosis in the long run (Organization, 1995).

The study has its weaknesses like the small sample size, and the population is comprised of males exclusively; in addition, the age of participants and short intervention periods do not provide the analytical power of the statistical and reduces the external validity of the results. In addition, there is only one outcome measure, namely, rate pressure product (RPP), which provides a limited assessment of the overall functional and clinical improvement. Finally, it is a single-centre study, and therefore it may not be representative of the outcome in more heterogeneous groups of patients or clinical groups.

5. Conclusions

This was a randomized clinical trial in which the response of circuit training, resistance training and the impact on the skeletal muscle strength and functional capacity of 34 men with a coronary artery bypass graft surgery was evaluated. The main results show that:

Both Circuit Training and Resistance Training Protocols were successful: The vast gains in RPP were achieved in both training groups (circuit training pre: 116.18 - post: 94.83, $p<0.0001$) and resistance one's training groups (pre: 116.41 - post: 97.96, $p<0.001$).

Equivalent effect: No significant difference was found between the level of effectiveness of the groups at post intervention (p=0.0971) and this demonstrated that the circuits training and resistance training lead to the same level of myocardial oxygen demand improvement. The two modalities were safe in both low-risk post-CABG patients (carefully selected) as neither of the groups reported having angina in the testing or the training. Strength benefits: Both circuit training and resistance training were effective to build upper and lower extremity muscle strength to enable them re-occupy their occupational and leisure activities.

Conversely, the limitations provide future recommendations that are larger in sample size, greater in age, mixed-gender, long-term training responses, include other outcome measures and multi-centre studies in diverse populations and contexts.

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