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Effects of High-Intensity Aerobic Interval Training on Cardiopulmonary Function in Patients With Chronic Heart Failure at The University Teaching Hospital, Lusaka, Zambia

Mikoloni Mary Musonda[1,*], Nkhata Loveness A., Goma Fastone M.

Department of Physiological Sciences, University of Zambia School of Medicine,
P.O. Box 32379 Lusaka, Zambia

***Corresponding author Email: marymikoloni@gmail.com**

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ABSTRACT

Chronic heart failure patients present with various symptoms, such as fatigue and dyspnea, adversely affecting their quality of life. Heart failure is a complex disease and a major cause of morbidity and mortality in developed and developing countries, including Zambia. Through studies undertaken, high-intensity aerobic interval training has been recommended in patients with chronic heart failure to help improve symptoms and, consequently, the quality of life. Minimal research pertaining to the effectiveness of aerobic exercise on various physiological parameters such as peripheral oxygen saturation, cardiopulmonary capacity and quality of life have been done in Africa and Zambia.

This study evaluated the physiological effects of high-intensity aerobic interval training on the cardiopulmonary function in New York Heart Association (NYHA) Class II and III chronic heart failure patients with a focus on peripheral oxygen delivery/saturation, cardiopulmonary capacity and the quality of life. This study utilised the Randomised Clinical Trial (RCT) study design, and the study population was selected from the University Teaching Hospital-Heart Clinic in Lusaka, Zambia.

A total number of 42 patients participated and were randomly assigned to the two arms of the study. Twenty-one (21) were assigned to the interventional group (IG) and 21 to the control group (CG), respectively. The IG underwent a 12-week aerobic HIIT exercise-training programme, while the CG was subjected to 30 minutes of walking on a treadmill for the same period of 12 weeks. The expected primary outcomes were the baseline to endline differences in oxygen delivery/saturation readings, cardiopulmonary capacity test readings and the quality of life (measured using the Minnesota questionnaire) for both groups. The results obtained from the pulse oximeter readings showed an increase in the oxygen saturation readings (97.90 to 98.62%), 6-minute walk distance readings (360.05 m to 429 m) and the questionnaire score totals of the different dimensions (physical, emotional/mental and socio-psychological factors) of the questionnaire (p-value;0.0001) of the IG. The CG oxygen saturation readings (97.38 % to 97.90%) and 6-minute walk test scores (359.14 to 370.9 m) showed minimal change. While the questionnaire scores showed a statistical difference in the emotional/mental (p-value < 0.0001), physical (p=0.005)

and socio-psychological factors (p-value < 0.0001). High-intensity aerobic interval training has shown to improve peripheral oxygen delivery, cardiopulmonary capacity and quality of life in chronic heart failure patients; hence, it must be considered an adjunct therapy aside from pharmacological management in stable chronic heart failure patients in Zambia.

Keywords: Chronic Heart Failure, Quality of Life, Peripheral Oxygen Delivery, Cardiopulmonary Capacity, Minnesota Questionnaire.

INTRODUCTION

Chronic heart failure (CHF), otherwise known as congestive heart failure or heart failure (HF), is defined by Dassanayaka and Jones (2015), as a clinical syndrome caused by structural and functional defects in the myocardium resulting in impairment of ventricular filling or the ejection of blood. Chronic heart failure is rapidly becoming a global concern and is a major cause of death and disability, especially in low and middle-income countries. The current worldwide prevalence of heart failure stands at 64.34 million cases, which translates to affecting about 8.52 per 1,000 inhabitants (Lippi, and Sanchis-Gomar, 2020). It affects approximately 2–5% of adults aged 65 to 75 and >10% of adults aged 80 and older, and it is more frequent in men than in women (Klindtworth et al., 2015; Mosterd et al., 2007). In Zambia, chronic heart failure is one of the leading non-infectious causes of death among hospitalised patients at the University Teaching Hospital (UTH) in Lusaka (Chansa et al., 2014). CHF patients. Patients with heart failure face significant decreases in functional status, multiple hospital admissions, high mortality, multiple physical and psychological symptoms and a diminished quality of life (Zambroski et al., 2005). Very minimal research pertaining to the effect of Aerobic High Interval training in chronic heart failure has been done in Africa and, to be precise, in Zambia. Management of heart failure in Zambia is mainly through medical intervention, while other treatment options like physiotherapy are infrequently engaged.

This study provides a platform to employ other non-pharmacologic treatment options. The aerobic exercise is said to improve the quality of life in heart failure, but its effect on general health status is not reported (Ambrosy et al., 2017). Aerobic high-intensity interval Exercise (HIIE) is defined as exercises that consist of repeated bouts (periods) of high-intensity exercise interspersed with recovery periods of rest (Meyer et al., 2013). Exercise training improves the quality of life and cardiopulmonary fitness in patients with CHF. Some studies have also suggested that exercise training improves clinical prognosis. In addition, and more significantly physiological systemic effects of this exercise intervention include improving vascular reactivity, vascular reperfusion, and increasing oxygen reuptake and muscle strength. Great importance is attached to this study because it brought out the beneficial effects of aerobic high-interval training in chronic heart failure, thereby supporting the recommendation of using this exercise regime as an adjunct therapy to pharmacological intervention in chronic heart failure management in Zambia.

METHODS AND MATERIALS

This randomised clinical trial (RCT) study design evaluated the effect of aerobic high-interval training on the cardiopulmonary function of chronic heart failure patients (NYHA class II and III). A sample size of forty-two (42) participants was selected from the University Teaching Hospital in Lusaka, Zambia. Twenty-one (21)

participants were randomly assigned to the control and intervention group using simple randomisation. The IG was assigned to a 12-week aerobic HIIT programme and the CG 30-minute treadmill walk for the same duration. Data collection tools utilised included the Minnesota Living with Heart Failure Questionnaire (MLHFQ) to record the quality of life, a pulse oximeter to record the oxygen saturation and the 6-minute walk test to measure the cardiopulmonary capacity. A pilot study was done on seven randomly selected chronic heart failure patients with the same case description (NYHA class II and III).

Data analysis was done using analysis of variance (ANOVA) and summarised using descriptive statistics. All statistical tests were performed at a 5% significance level or 95% confidence interval with a p-value of <0.05 to determine statistical significance. Associations and differences were expressed as standard deviation and meant comparing baseline and endline (after 12 weeks) results.

Aerobic HIIT Exercise Protocol (Intervention group)

The participants from the intervention group were subjected to 12 weeks of supervised high-intensity aerobic interval training for 30 minutes three times a week. Vitals were taken every time before the commencement of any exercise programme. The exercise programme began with warm-up exercises, and then the main exercise intervention the, aerobic HIIT. The interspersed interval exercise comprised walking on a treadmill and cycling on an ergometer for intervals of 30 seconds before each period of rest, which lasted for 120 seconds. Cool-down exercises and BP and oxygen saturation readings were conducted routinely at the end of every exercise session to allow for patient monitoring post-exercise intervention. Cardiopulmonary endurance capacity, oxygen saturation and quality of life parameters were evaluated at baseline and 12 weeks.

Ethical approval was sought and obtained from the Biomedical Research Ethics Committee at the University of Zambia (UNZABREC).

RESULTS

Demographic and Clinical Characteristics of Participants

A total number of 42 participants participated in this study, 51.72% of which were female from the intervention group and 48.28% from the control group, respectively. The mean age was 43.1 in the intervention group and 47.2 in the control group, respectively.

Table 1: Participants Demographic Description

Variable	Mean Inter	Mean Contr	SD Inter	SD Contr	% Inter	% Contr	Freq Inter	Freq Control
Age 20-30 30-40 40-50 50-65	43.10	47.2	13.23	10.55				
Male					46.15	53.85	6	7
Female					51.72	48.28	15	14
Weight	73.38	77.71	20.87	10.77				
Body mass Index (BMI)	28.81	30.89	7.17	4.15				

Effectiveness of High-intensity aerobic Interval training on cardiopulmonary and Peripheral Oxygen Delivery

Associations between Baseline and Endline Variables

In the post and the pre-exercise analysis, we investigated if associations existed between our parameters of interest at baseline and endline in both the control and intervention group. The results in Table 3 show no significant association, as all the p-values were greater than 0.05. Therefore, there was insufficient evidence to reject the null hypothesis.

Table 2: Associations Between Pre Exercise, Post Exercise Versus Individual Known Variables

Variable	Pre-exercise		Post-exercise		
	Intervention group (Mean, SD)	Control group (Mean, SD)	Intervention group (Mean, SD)	Control group (Mean, SD)	p-value
Heart rate	74.10 (12.46)	79.86 (5.79)	73.67 (8.74)	83.24 (6.97)	0.782
Score	47.24 (14.66)	43.81 (8.12)	32.38 (8.11)	40.62 (8.56)	0.320
6MWT score	360.05 (58.82)	359.14 (65.88)	429 (66.19)	370.90 (65.63)	0.166
Oxygen saturation	97.90 (1.14)	97.38 (1.24)	98.62 (0.74)	97.90 (0.99)	1.000

Effectiveness of High-intensity Aerobic Interval Training on Quality of Life

The MLHFQ was used to evaluate the effectiveness of aerobic HIIT on the different dimensions (physical, emotional/ mental and socio-psychological) of the questionnaire.

The physical domain of the MLHFQ included: sitting or resting during physical activity, one's ability to walk or climb stairs, house chores, presence of oedema, going places, sleeping at night, shortness of breath and fatigability. A comparison was made between the pre and post-physical factor MLHFQ scores and a decline of scores for the participants was seen. A reduction from an average of 50 at baseline to an average of 24 at the endline was observed after the 12-week intervention in the IG. The reduction in the scores showed a statistically significant improvement in the quality of life ($p < 0.001$).

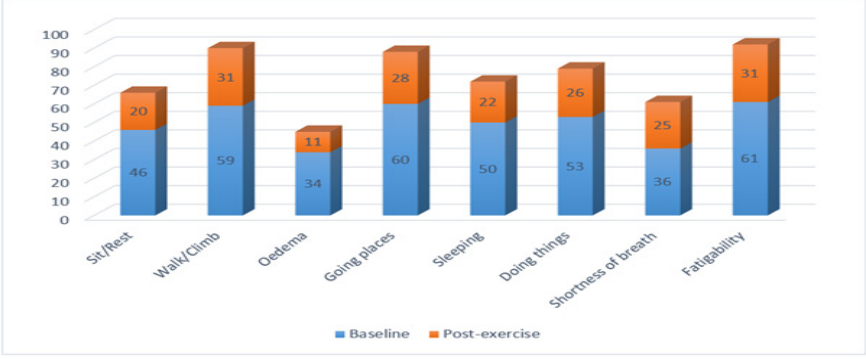

Figure 1: Changes in the MLHF Physical Factor Scores in the Intervention Group at Baseline and Endline

The comparison was made between the baseline and endline physical factor MLHFQ scores in the control group, average baseline score was 55 and 46 at the endline. A change from an average score of 55 at baseline to 46 at the endline was recorded with p = 0.0055.

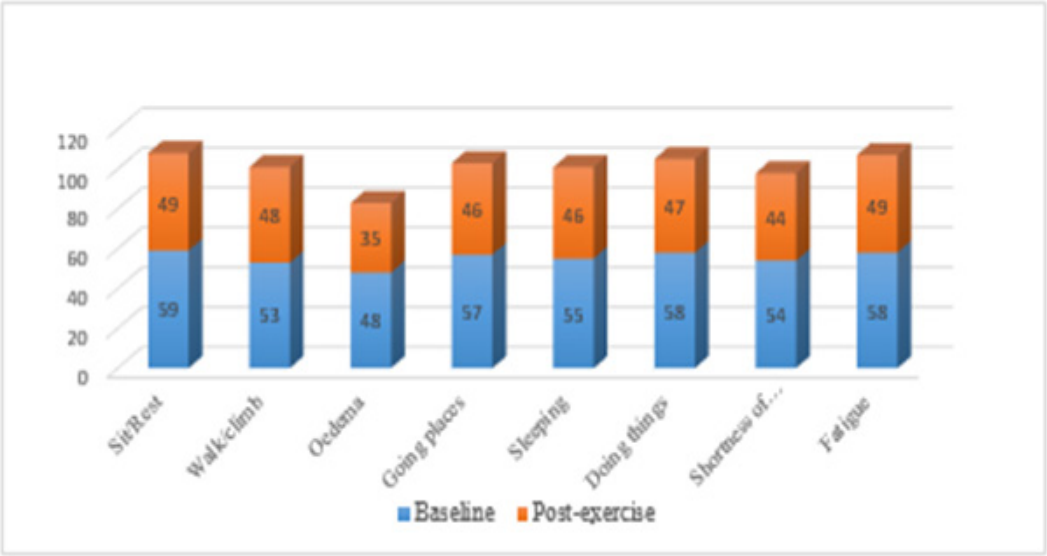

Figure 2: Change in MLHFQ Physical Factor scores in the Control Group at Baseline and Endline

The emotional/mental domain evaluated the following; if the patient is a burden to others, loss of self-esteem, worry, memory loss and depression. A reduction was recorded in the test scores from baseline to endline in the IG. The average score was at 58 baselines and 20 at the endline, depicting an improvement in the emotional/mental dimension of the MLHFQ after the aerobic HIIT intervention. The reduction in cores was statistically significate with p < 0.001.

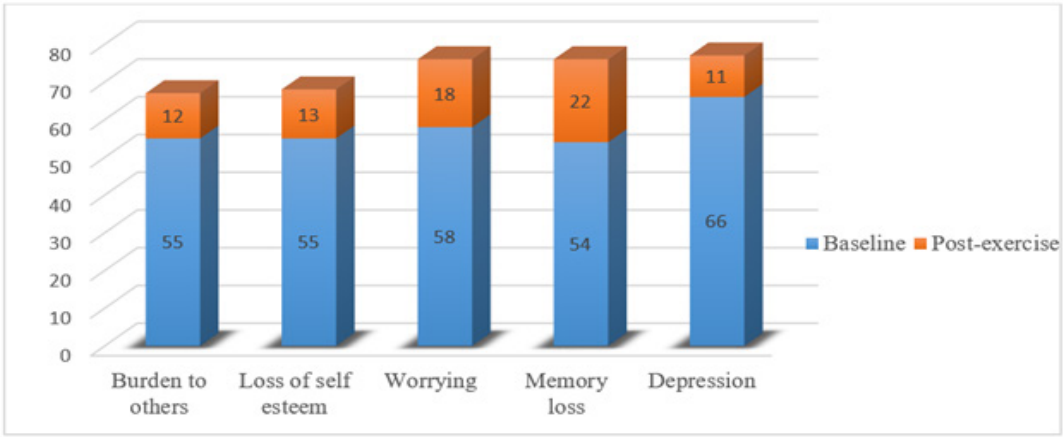

Figure 3: Change in MLHFQ Emotional/Mental Scores in the Interventional Group from Baseline to Endline

A comparison was made between baseline and endline emotional/mental factors in the control group. The average baseline score was 72, while 35 was the average endline score. A significant reduction was seen, with a p-value < 0.001.

Figure 4: Change in MLHFQ Emotional/Mental Scores in the Control Group at Baseline and Endline

The socio-psychological domain of the MLHFQ includes; working, earning a living, recreation, sexual difficulties, eating less, hospital admissions, side effects and cost. A drastic reduction in the MLHFQ socio-psychological factor scores in the intervention group was noted, as depicted in Figure 3. The average baseline score was 48 and 27 after the intervention. The reduction was statistically significant with p < 0.001.

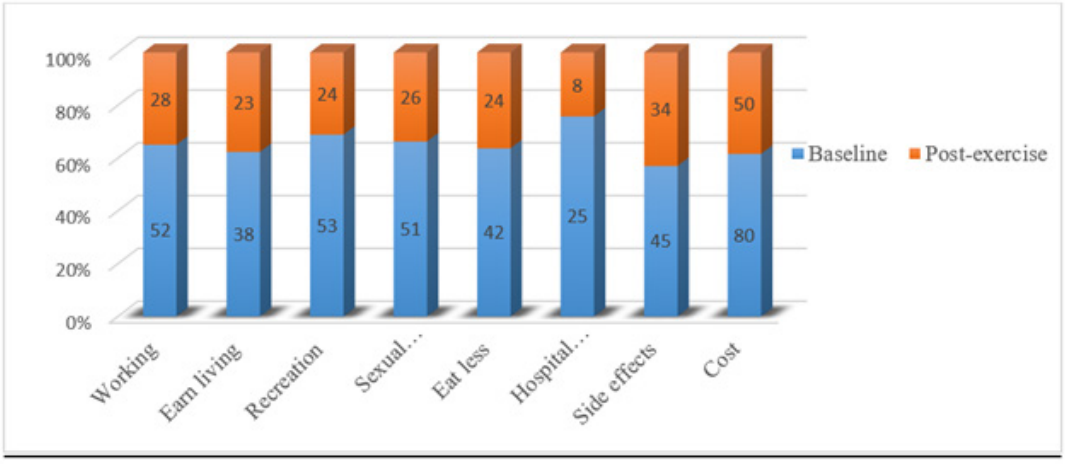

Figure 5: Changes in the MLHFQ Socio-psychological Scores in the Intervention Group at Baseline and Endline

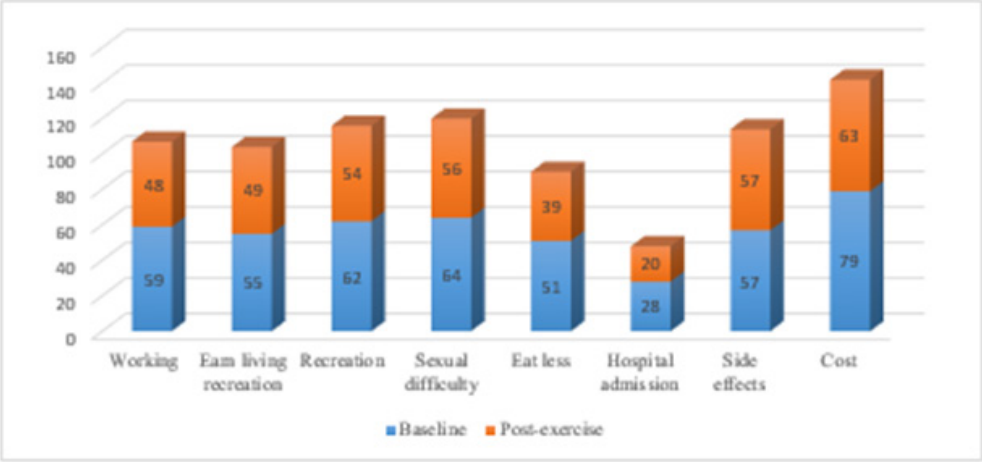

Figure 6: Change in the MLHFQ Socio-psychological Scores in the Control Group at Baseline and Endline

The baseline and endline socio-psychological factors scores of the MLHFQ were recorded, and a comparison mad made between the endline and baseline scores. The average scores were 57 at baseline and 48 for the endline score. A reduction was seen, with a p-value < 0.001.

Differences in Means and Standard Deviations in Intervention and the Control Group

The result from Table 3 shows the means and standard deviations in each dimension (physical, emotional/mental and socio-psychological) of the MLHFQ questionnaire for the intervention and control group. All mean variables at baseline and endline for each dimension are presented in Table 4 below, and a drastic reduction was seen in means and standard deviations of the interventional group, translating into an improved quality of life. While in the control group, a significant reduction was only recorded in the emotional/mental dimension and not so much in the other two dimensions.

Table 3: Estimating the Means and Standard Deviations for the Intervation and Control Group

Variable	Number of participants (n)	Baseline mean (SD)	Endline mean (SD)
Physical (IG)	21	19.96 (6.54)	8.95 (4.27)
Emotional/Mental (IG)	21	13.91(4.69)	3.52 (2.18)
Socio-psychological (IG)	21	18.83 (6.22)	9.62 (4.41)
Physical (CG)	21	20.85 (3.02)	17.57 (4.14)
Emotional/Mental (CG)	21	17.23 (1.70)	8.33 (2.65)
Socio-psychological (CG)	21	21.71 (2.49)	18.38 (2.52)

Test for Differences Using One-Way Analysis of Variance

A statistical difference was found from baseline to endline in all the dimensions of the MLHFQ (physical factor MLHFQ scores, p-value < 0.0001, socio-psychological, pp-value< 0.0001 and emotional/, mental MLHFQ scores p-value < 0.0001) for the IG. The mean percentage change recorded for the IG in all dimensions was significant and more superior, as depicted in Table 4 below. A minimal reduction was seen in the MLHFQ scores recorded at baseline and endline for all three dimensions for the control group, and this is demonstrated by the minimal mean percentage change recorded in the dimensions. Statistical differences were recorded in all three dimensions (physical MLHFQ scores p-value=0.0055, emotional/mental MLHFQ scores p-value < 0.0001 and socio-psychological MLHFQ scores p < 0.0001).

Table 4: Testing for any differences in the intervention and control group between the baseline results and the endline results.

Factor	Variables	Mean percentage change	F-statistic	P-value
Physical (IG)	Sit/Rest, Walk/ Climb, Oedema, Going places, Sleeping, Doing things, Shortness of breath and Fatigue	55%	43.28	<0.0001
Emotional/Mental (IG)	Burden, Loss of S.E, Worrying, Memory and Depression	75%	31.99	<0.0001
Socio-psychological (IG)	Working, Earn a living., Recreation, Sexual difficulty, Eat less, Hosp ad, Side Effects and Cost	50%	86.54	<0.0001
Physical (CG)	Sit/Rest, Walk/ Climb, Oedema, Going places, Sleeping, Doing things, Shortness of breath and Fatigue	16%	8.63	=0.0055
Emotional/Mental (CG)	Burden, Loss of S.E, Worrying, Memory and Depression	52%	167	<0.0001
Socio-psychological (CG)	Working, Earn a living., Recreation, Sexual difficulty, Eat less, Hosp ad, Side Effects and Cost	15%	18.57	<0.0001

DISCUSSION

The outcomes from the aerobic HIIT intervention revealed that this exercise intervention improved the physiological parameters (cardiopulmonary capacity and quality of life) more in the intervention group, unlike the control group. This was evidenced by comparing the results recorded at baseline and endline for all the parameters under study, in both intervention and the control, respectively. High-Intensity Aerobic Interval Exercises (HIIE) are defined as exercises that consist of repeated bouts (periods) of high-intensity exercise interspersed with recovery periods of rest (Meyer et al., 2013). In this study, the participants in the intervention group fell in the high exercise intensity bracket from the exercise intervention when their heart rate records became higher than 85 b/min. The physiological effect of aerobic HIIT includes improving oxygen reuptake, vascular reperfusion and strengthening of muscles. Until now, heart failure is considered a condition best treated by the prescription of bed rest in certain places (Larsen and Dickstein, 2005), including Zambia. The (Meyers 2008) perception of risks during exercise is said to be high, and (Larsen and Dickstein, 2005) the beneficial effects of exercise remain to be appreciated and well understood. However, the benefits of exercise by stable chronic heart patients, as is the case in our study, are well documented, and other benefits include improved lung volumes, functional capacity and health-related quality of life (Recommendations for exercise in chronic heart failure patients, 2001).

A total of 42 participants were randomly selected for this study from chronic heart failure patients seen at the UTH heart clinic between January to March 2021. Of the total research population, 69% were female, and 31% were male. According to Strömberg and Mårtensson (2003), men have a higher incidence of heart failure, but the overall prevalence rate is similar in both sexes since women survive longer after the onset of heart failure. This study had more women enrolled than men, which was attributed to the fact that women have better health-seeking behaviour than men. The life situations for men and women with heart failure differ (Strömberg and Mårtensson, 2003). The age range for participants in this study was from 18 to 63 years and peaked around age 38. Most studies, though, like the one done on the spectrum of heart failure in sub-Saharan Africa by Mandi et al. (2020), have shown that the age most affected by heart failure is 70 years and above, which is not quite reflective of the findings in this research. We could further attribute this poor detection of chronic heart failure to the reduced life expectancy in our country Zambia.

Peripheral Oxygen Saturation/Delivery

The oxygen saturation readings changed by about 1% (average from pre-97.90 % to post-98.62 %) in the intervention group, which was assumed as a potential improvement. No improvement was recorded in the oxygen saturation reading in the control group (pre-97.38 % to post-97.90 %). The test for association between the baseline and endline changes in both the IG and

CG gave a p-value < 1. Participants in both the intervention and control group were not desaturating at the time of enrollment. Therefore, whatever change took place was recorded. According to Smart et al., 2013, intermittent exercise like aerobic HIIT improves oxygen metabolism because of a greater generation of large shear stress forces within the endothelium, which leads to improvements in endothelial function and increased muscle mass. The potential minimal improvement recorded in the intervention group can be attributed to vascular reactivity, improved vascular reperfusion and the anti-inflammatory effect of aerobic HIIT.

Exercise Capacity and Cardiopulmonary Capacity

An improvement in the cardiopulmonary capacity was shown, as evidenced by the readings of the 6-minute walk test. The 6-minute walking test (6MWT) is a reliable and well-tolerated test for the assessment of the functional capacity of patients with HF. In this study, the distance in the 6MWT increased significantly (360.05 to 429 metres) in the intervention group after 12 weeks of aerobic HIIT intervention. A minimal change was recorded in the 6MWT distances for the control group, but it was insignificant (359.14 to 370.90). A test for association between the baseline and endline results in both groups gave a p-value < 0.166. The improvement in the 6MWT distance in this study shows that the aerobic HIIT exercise programme effectively increased cardiopulmonary functional capacity in chronic heart failure patients. The 6MWT has shown a good correlation with the peak VO2 from cardiopulmonary exercise test, is much easier to perform, and it reflects the daily activities of chronic heart failure patients well. Since exercise capacity is a major prognostic factor in chronic heart failure, a less complicated test, the 6MWT, was used to measure the functional and cardiopulmonary capacity. This test correlates well with increasing the oxygen reuptake and assessing how well a chronic heart failure patient can execute daily activities.

Quality of Life

The quality of life in chronic heart failure was assessed before and after the intervention to assess the impact of aerobic HIIT on the physical, emotional/mental and social-psychological dimensions. QoL was assessed using a valid, specific, reproducible tool, the Minnesota Living with Heart Failure Questionnaire.

Physical Factors

At the beginning of the intervention, all participants had moderate physical limitations. Notable improvements in the intervention group were evident by the sixth week of the aerobic HIIT intervention, but it was more marked by week 12. Aerobic HIIT has a high impact on the final physical domain score of the MLHFQ in stable chronic heart failure patients (Ulbrich et al., 2015). A statistically significant improvement was seen in the MLHFQ scores of the physical dimension (p-value< 0.0001 and p= 0.0055) of both the intervention and control group although the IG had a higher improvement rate as shown by the mean percentages (55% -IG and 16%-

CG) recorded. By the time it was the twelfth week of exercise intervention, a marked improvement was seen in the IG. According to Tu et al., (2014), exercise training was associated with a demonstrable benefit in the symptoms of depression in clinically stable HF patients.

Emotional/Mental Factors

Chronic heart failure, aside from physical symptoms, is also accompanied by many emotional/mental challenges. Depression, one of the costliest and most common mental disorders, is reported to be associated with lower quality of life (QoL) in several studies (Cho et al., 2019). Depression is said to be a major issue in heart failure (HF), and it is present in about one in five HF patients, with about 48% of these individuals having significant depression (Mbakwem et al., 2016). At baseline, many participants in both the intervention and control group exhibited emotional/mental symptoms. Notable changes in these emotional/mental factors began visibly and evidently improving. Statistically significant improvement was seen in the emotional/mental dimension MLHFQ scores (p-values < 0.0001) in both the intervention and control group. Scores in the intervention group were the most significant and superior, and this was shown by the greatly reduced emotional/mental MLHFQ scores and mean percentage changes (75% intervention group and 52% control group), by the second week of aerobic HIIT intervention for the IG.

Socio-Psychological Factors

Improvements in the socio-psychological dimension were notable by the sixth week and more marked by the twelfth week of the exercise intervention for the IG, while a minimal improvement was recorded in the CG. Similar findings have also been reported in other studies (Belardinelli et al., 2000). The socio-psychological dimension was found to be statistically significant (p-value<0.0001) in the IG at the endline and also statistically significant in the control group (p-value < 0.0001). Both groups showed a reduction in the MLHFQ scores of this dimension though more in the intervention, unlike the control group, as also supported by the mean percentage changes calculated (50% intervention group and 15% control group).

LIMITATIONS

The stereotype surrounding exercise and chronic heart failure and exercise made it very difficult during recruitment as the researcher had to constantly explain and reassure the would be participants that these exercises were tailored to their level and they would physically and medically be of benefit to them. The inevitable confounders such as beta-blockers, anti-failure medication and anti-hypertensive medication may have affected the outcome of the study in some way, but we can safely conclude that most of the change was due to the exercise intervention because despite some participants being on one or more combinations of these drugs before, they still presented with a poor and compromised quality of life at baseline.

CONCLUSION

In this study, it has been proved that high-intensity interval training has shown to be more effective in improving the parameters of physical fitness and quality of life in chronic heart failure patients than oxygen delivery/saturation. This is a very important finding, given that a better functional capacity translates into improved symptoms and quality of life. The aerobic high-intensity interval exercises have been shown to be more efficient, meaning that the same energy expenditure can be performed in a shorter time period, which may be an important practical aspect to consider during a rehabilitation programme. Aerobic HIIT has shown the potential to improve vascular reperfusion, oxygen saturation, cardiopulmonary and physical fitness.

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