JEPonline
Journal of Exercise Physiologyonline

Clinical Exercise Physiology

THE CARDIOPULMONARY RESPONSES OF ELLIPTICAL CROSSTRAINING VERSUS TREADMILL WALKING IN CAD PATIENTS

Marianne L. Sweitzer[1], Len Kravitz[1,2], Heidi M. Weingart[2], Lance C. Dalleck[2], Linda F. Chitwood[1], Erik Dahl[1]

[1]Department of Exercise Science and Leisure Management, The University of Mississippi; [2]Exercise Physiology Laboratories, The University of New Mexico

ABSTRACT

THE CARDIOPULMONARY RESPONSES OF ELLIPTICAL CROSSTRAINING VERSUS TREADMILL WALKING IN CAD PATIENTS. **Marianne L. Sweitzer, Len Kravitz, Heidi M. Weingart, Lance C. Dalleck, Linda F. Chitwood, Erik Dahl**. JEPonline. 2002;5(4):11-15. The purpose of this study was to compare the cardiopulmonary responses of elliptical cross-training versus treadmill walking in CAD patients (9 men, 3 women). Subjects performed four randomized, submaximal exercise trials (treadmill=2 trials, elliptical cross-trainer=2 trials) based upon different ratings of perceived exertion (RPE); 10 and 14. Steady-state measurements for oxygen consumption (VO_2), heart rate (HR), blood pressure (BP) and expired ventilation (VE) were obtained for each trial. A repeated measures 2-way ANOVA was used to determine differences for VO_2, HR, BP, and VE between the two modes of exercise. During exercise trials at the 10 RPE level it was found that VO_2 (12.6±2.2 vs 11.2±3.4 ml/kg/min), HR (110±19 vs 98±23 b/min), and VE (27.9±7.1 vs 23.6±9.6 L/min) were significantly higher (p 0.05) while elliptical cross-training compared to treadmill walking. During exercise trials at the 14 RPE level it was found that HR (127±13 vs 115±19 b/min), VE (40.7±7.16 vs 33.3±8.85 L/min), systolic BP (176±21 vs 166±19 mmHg) and diastolic BP (75±10 vs 69±7 mmHg) were significantly higher (p 0.05) while elliptical cross-training compared to treadmill walking. In conclusion, for this sample of CAD patients, this study revealed that the elliptical cross-trainer produced greater cardiopulmonary responses when compared to the treadmill at equivalent levels of RPE. However, the greater cardiovascular strain for the RPE=14 condition despite a similar VO_2 indicates concern for the use of the elliptical cross-training for individuals with CAD unfamiliar with this mode of exercise.

Key Words: Cardiac Rehabilitation, Oxygen Consumption, Heart Rate, Submaximal Exercise, Rating of Perceived Exertion

INTRODUCTION

Cardiac rehabilitation is based upon the concepts and ideas developed by Herman Hellerstein, which date back to the 1950's (1). Cardiac rehabilitation has evolved over the past 50 years into a program which has two basic

goals: to improve the health status of the cardiac patient with coronary artery disease (CAD) and to reduce the risk of recurrence of cardiac events (1). In order to achieve these goals, most cardiac rehabilitation programs have specific curricula targeted towards assisting the patient in multidisciplinary fields, such as physical fitness, social interaction, nutrition counseling, and psychological support (2). The demographics of the cardiac rehabilitation population was once predominantly comprised of primarily male coronary artery bypass graft (CABG) patients, but now includes both the young and elderly, males and females, those with chronic comorbidities (diabetes, hypertension, hyperlipidemia), and persons who have had other surgeries such as angioplasty (1, 3).

Aerobic exercise training has long been used in the treatment of patients with CAD (4). Schuler et al. (5) noted that the progression of CAD might be slowed and even reversed in patients participating in a low-fat diet and regular exercise program intervention. Exercise training has been shown to lower heart rate (HR) and blood pressure (BP), improve high-density and low-density lipoprotein cholesterol balance, decrease insulin resistance, and help to decrease body weight (6). These benefits are often enhanced by a multidisciplinary cardiac rehabilitation program involving education, counseling, supervised exercise, and nutrition evaluation (1).

Due to the multiple physical needs of patients in cardiac rehabilitation, it is important to incorporate different modes of exercise. However, the exercise-induced stress on the cardiovascular system can differ with various modes of exercise, thus eliciting different risks and training effects (7,8). Some of the most common exercise modalities used in cardiac rehabilitation are the treadmill, cycle ergometer, and seated rowing machine. Previous investigations in asymptomatic populations have found that the treadmill produces higher oxygen consumption (VO_2) and HR values, with lower ratings of perceived exertion (RPE) scores than other modes of exercise (5,9,10). However, due to the relatively high impact characteristics of treadmill walking and running, many patients cannot safely utilize this mode of exercise. The elliptical cross-trainer is a new, low-impact exercise modality that may be beneficial for use in the cardiac rehabilitation setting. Presently, there has been no research done on this modality in a cardiac rehabilitation setting. Therefore, the purpose of this study was to determine the cardiopulmonary effects of elliptical cross-training versus treadmill walking in CAD patients.

METHODS
Subjects
Twelve subjects (9 men, 3 women; ages 47 to 79 years) were recruited from a local cardiac rehabilitation center. All subjects had previous cardiac procedures and/or events (CABG, n=9; angioplasty, n=2; myocardial infarction, n=1) and were classified as Class I functional level from the New York Heart Association Functional Classification of Heart Disease (11). See Table 1 for a complete description of the subject characteristics. Each subject had approval to participate in this study from his/her cardiologist or cardiac surgeon, and gave informed consent. The study and consent were approved by the university Institutional Review Board.

Table 1. Subject Characteristics (n=12)

Parameter	Measurement
Age (years)	63.6±9.6
Height (cm)	174.0±9.3
Weight (kg)	82.4±13.9
Resting HR (b/min)	72.5±10.2
Resting SBP (mmHg)	129.6±19.4
Resting DBP (mmHg)	69.0±10.2

Values are Mean±SD

Subjects were accustomed to treadmill exercise or walking and all had one familiarization session on the lower body only elliptical cross-trainer (Precor, Inc., Woodinville, WA) prior to testing. Subsequent to any testing session, subjects were given detailed instruction on the exercise testing protocol and Borg's Rating of Perceived Exertion (RPE) Scale (12). The exercise testing consisted of four randomized, submaximal exercise trials (treadmill=2 trials, elliptical crosstrainer=2 trials), lasting five minutes and performed at two different RPE intensities (RPE 10, RPE 14). The order of the trials was assigned using a balanced Latin square design (13). A physician was present for all exercise trials.

Subjects warmed up for five minutes at 1.0 mi/hr on the treadmill and then rested in a seated position for five minutes prior to the first trial and again for five minutes between each trial. All exercise trials were performed on the same day for each subject. For each exercise mode, subjects exercised at a RPE of 10 and a RPE of 14. VO_2 and expired ventilation (VE) were analyzed every 20 seconds with open circuit spirometry using a Sensor Medics Vmax series 29 metabolic cart (Sensor Medics Corporation, Yorba Linda, California). Data from the last two minutes of data from each trial were averaged and used for statistical analysis. HR and cardiac cycle were monitored continuously with a 12-lead EKG. Heart rate was recorded every two and a half minutes of exercise and at the five-minute mark of recovery following each trial. BP was also monitored by auscultation, using a stethoscope and sphygmomanometer, every two and a half minutes and at the five-minute mark of recovery after each trial.

Data for steady state VO_2, HR, BP, and VE were analyzed using a repeated measures 2-way ANOVA. When an interaction was significant, specific mean comparisons were performed using a Tukey HSD test. Statistical significance was accepted at $p < 0.05$.

RESULTS

The results of this study are summarized in Table 2. There were no significant differences (F=0.006, p>0.05) in VO_2 between the elliptical cross-trainer and treadmill at the 14 RPE intensity level. There was, however, a significant difference between modes (F=12.85, p<0.05 and F=10.17, p<0.05, respectively) in relative and absolute VO_2 at the 10 RPE intensity level. Results for HR revealed a significant difference (F=35.88, p<0.05 and F=39.26, p<0.05, respectively) between modes at both the 14 RPE and 10 RPE intensities. VE data were also found to be significantly different (F=38.92, p<0.05 and F=12.86, p<0.05, respectively) between modes at both the high and low RPE levels. A significant difference between modes was also noted in both systolic and diastolic blood pressure at the 14 RPE intensity (F=5.74, p<0.05 and F =37.37, p<0.05). However, no differences in systolic and diastolic blood pressure at the 10 RPE intensity level were found (F=1.29, p>0.05 and F=2.63, p>0.05).

Table 2. Cardiopulmonary Responses of the Elliptical Cross-trainer (ET) vs. Treadmill (TM)

	RPE = 14		RPE=10	
Parameter	*ET*	*TM*	*ET*	*TM*
VO₂ (ml/kg/min)	15.79 ± 2.94	15.76 ± 3.39	12.62 ± 2.22	11.16 ± 3.44
VO₂ (L/min)	1.30 ± 0.33	1.30 ± 0.37	1.05 ± 0.27	0.94 ± 0.37
HR (b/min)	126.5 ± 13.2 *	114.6 ± 18.6	109.9 ± 19.4	97.4 ± 23.2
VE (L/min)	40.71 ± 7.16 *	33.27 ± 8.85	27.86 ± 7.11	23.59 ± 9.61
Systolic BP (mmHg)	176 ± 21 *	166 ± 19	154 ± 18	149 ± 19
Diastolic BP (mmHg)	75 ± 10 *	69 ± 7	69 ± 7	68 ± 7

*Values are Means±SD; * ET High is significantly different from TM High; ET Low is significantly different from TM Low*

DISCUSSION

Cardiac rehabilitation is important to CAD patients because it assists them in improving health and prevents the risk of future cardiac events through diet and exercise lifestyle changes (1). One meta-analysis revealed that cardiac rehabilitation resulted in a 24% reduction in all-cause mortality and a 25% reduction in cardiovascular mortality (14). Within the cardiac rehabilitation setting, the prescription of exercise intensity is accomplished through different monitoring approaches including HR, RPE, and METs (15). Careful regulation of these variables during exercise can elicit the desired training effect in the CAD patient while limiting the risk of abnormal symptom development. Due to the varying abilities and limitations of CAD patients, treadmills, stationary cycle ergometers, and rowing ergometers are often utilized for exercise. In previously researched healthy populations, the treadmill has produced the greatest cardiopulmonary responses when compared to other

exercise modalities (10,16,17). Alternate exercise modalities have largely been overlooked in research for their potential application and effectiveness for the cardiac rehabilitation population. From our review, this study is the first to investigate the cardiopulmonary effects of elliptical cross-training versus treadmill exercise in patients with CAD. Results indicated that the elliptical cross-trainer produced higher metabolic, cardiovascular and ventilatory responses than the treadmill at equivalent levels of RPE.

Interpretation of results from the present study provides important implications for exercise prescription within the cardiac population. At both self-selected RPE levels, similar metabolic loads (VO_2) were achieved on both the elliptical cross-trainer and treadmill. Similarly, a study comparing the treadmill to a lower body only elliptical cross-trainer and an upper/lower body elliptical cross-trainer, in healthy college-aged subjects exercising at self-selected intensity, found no significant difference in VO_2 values (18). The mean VO_2 values for the lower body elliptical cross-trainer were 31.2 ml/kg/min compared to 31.4 ml/kg/min for the treadmill. Findings from the present study also suggest the elliptical cross-trainer has the capability of providing training benefits for CAD patients similar to the treadmill with regards to oxygen consumption and caloric expenditure.

Because the elliptical cross-trainer is low-impact compared to the treadmill, it may be a more favorable exercise modality for overweight patients or individuals with back, knee, or other lower-leg limitations. However, the significant differences found in HR and BP (see Table 2) between exercise modalities in the present study at both self-selected RPE levels suggest initial exercise prescription on the elliptical cross-trainer must be approached with prudence. Exercise intensity prescription utilizing a combination of HR and RPE generally corresponds to the appropriate target heart rate range (15). Our findings indicate this relationship may not be as accurate and consistent for individuals initially exercising on the elliptical cross-trainer. Increased HR and BP responses could have been influenced by the subject's lack of sufficient mode familiarity, holding on firmly to the handrails, and possible nervousness with the motion of the elliptical cross-trainer. Observations from a local cardiac rehabilitation facility suggest these differences are transient and become non-existent with further modality experience on the elliptical cross-trainer (personal communication). Nevertheless, a conservative and deliberate approach is suggested in the initial prescription of exercise intensity on the elliptical cross-trainer so as to not place too great a demand on the cardiovascular system, which may precipitate dangerous arrhythmias or myocardial ischemia (15). Therefore, a recommendation, within the limits of this investigation, is that the incorporation of elliptical cross-training exercise with CAD patients should include a familiarization period with a gradual progression in intensity and duration.

Address for correspondence: Len Kravitz, Ph.D., Exercise Science Program, Department of Physical Performance and Development, Johnson Center #1160, Albuquerque, NM 87111; Phone: (505) 277-4136; FAX: (505) 277-9742, Email: lkravitz@unm.edu

REFERENCES

1. Bethell HJ. Cardiac rehabilitation: from Hellerstein to the millennium. *Int J Clin Pract* 2000;54:92-7.
2. Hare DL, Bunker SJ. Cardiac rehabilitation and secondary prevention. *J Cardpulm Rehabil* 1999;171:433-9.
3. Richardson LA, Buckenmeyer PJ, Bauman BD, Rosneck JS, Newman I, Josephson RA. Contemporary cardiac rehabilitation: patient characteristics and temporal trends over the past decade. *J Cardpulm Rehabil* 2000;20:57-64.
4. Fletcher G, Froelicher VF, Hartley LH. AHA medical scientific statement. Exercise standards: a statement for health professionals from the American Heart Association. *Circulation* 1990;82:2286-2322.
5. Schuler G, Hambrecht R, Senlierf G, et al. Regular physical exercise and low-fat diet effects on progression of coronary artery disease. *Circulation* 1992;86:1-11.

6. Perk J, Veress G. Cardiac rehabilitation: applying exercise physiology in clinical practice. ***Eur J Appl Physiol*** 2000;83:457-62.

7. Miles DS, Critz JB, Knowlton RG. Cardiovascular, metabolic, and ventilatory responses of women to equivalent cycle ergometer and treadmill exercise. ***Med Sci Sports Exerc*** 1980;12:14-9.

8. Howley ET, Colacino DC, Swensen TC. Factors affecting the oxygen cost of stepping on an electronic stepping ergometer. ***Med Sci Sports Exerc*** 1992;24:1055-8.

9. Niebauer J, Hambrech R, Marburg C, et al. Impact of intensive physical exercise and low-fat diet on collateral vessel formation in stable angina pectoris and angiorically confirmed coronary artery disease. ***Am J Cardiol*** 1995;76:771-5.

10. Thomas TR, Ziogas G, Smith T, Zhang Q, Londeree BR. Physiological and perceived exertion responses to six modes of submaximal exercise. ***Res Q Exerc Sport*** 1995;66:239-46.

11. Criteria Committee, New York Heart Association, Inc. Disease of the Heart and Blood Vessels, Nonmenclature and Criteria for Diagnosis (6th edition). Boston: Little and Brown, 1964.

12. Borg, G. Perceived exertion: a note on 'history and methods.' ***Med Sci Sports Exerc*** 1973;5.90-3.

13.   Keppell, G. Design and analysis: A researcher's handbook. London: Prentice Hall, 1983.

14.   Oldridge NB, Guyatt GH, Fisher ME, et al. Cardiac rehabilitation after myocardial infarction: combined experience of randomized trials. ***JAMA*** 1998;260:945-50.

15.   American College of Sports Medicine. ACSM's guidelines for exercise testing and prescription (6th ed.). Baltimore: Williams & Wilkins, 2000.

16. Buckley JP, Davis JA, Simpson T. Cardio-respiratory responses to rowing ergometry and treadmill exercise soon after myocardial infarction. ***Med Sci Sports Exerc*** 1999;31:1721-6.

17. Kravitz L, Robergs RA, Heyward VA, Wagner DR, Powers K. Exercise mode and gender comparisons of energy expenditure at self-selected intensities. ***Med Sci Sports Exerc*** 1997;29:1028-35.

18. Crommett A, Kravitz L, Wonsathikun J, Kemerly T. Comparison of metabolic and subjective response of three modalities in college-age subjects. ***Med Sci Sports Exerc*** 1999;31:S677.