©Journal of Sports Science and Medicine (2004) **3 (YISI 1),** 1-7
http://www.jssm.org

Young Investigator Special Issue 1

Research article

THE PHYSIOLOGICAL RESPONSES OF CHRONIC HEART FAILURE PATIENTS TO MAXIMAL STRENGTH TEST AND A BALKE INCREMENTAL TEST

Itamar Levinger [1] ✉, Roger Bronks [1], David V. Cody [2], Ian Linton [2] and Allan Davie [1]

[1] Southern Cross University, Lismore NSW 2480, Australia
[2] John Flynn Private Hospital-Gold Coast, TUGUN QLD 4224, Australia

Received: 17 March 2004 / Accepted: 22 July 2004 / Published (online): 01 November 2004

ABSTRACT
It has been demonstrated that resistance exercises may improve chronic heart failure (CHF) patients' functional ability and quality of life, however, physicians do not recommend this form of exercise because of a concern for reported increases in afterload and blood pressure (BP) during the exercise. This study compared the heart rate (HR), BP and rate pressure product (RPP) of CHF patients for a Balke incremental test and a maximal strength test (MS). Fifteen men diagnosed with CHF participated in the study. All subjects performed both a Balke incremental test and MS test for eight different resistance exercises. The subjects' HR and BP were monitored during the incremental test and immediately after each resistance exercise. HR, systolic BP and RPP were significantly lower during the MS test than during both the peak Balke incremental test and during exercise at 80% of peak VO_2 ($p < 0.05$). No significant RPP differences were found between upper and lower body resistance exercises ($p > 0.05$). The physiological responses in this study were less severe during a MS test than those reported during an incremental Balke treadmill test. Also the finding suggests that MS tests may be an acceptable method to assess the maximal strength of patients with moderate heart failure.

KEY WORDS: Chronic heart failure, incremental test, rate pressure product.

INTRODUCTION

A decrease in work capacity (Delp et al., 1997), exercise intolerance (De Sousa et al., 2000; Simonini et al. 1996; Sullivan et al. 1997) and a reduction in muscle mass and strength (Mancini et al., 1992; Pollock et al., 1998) are characteristics of people with chronic heart failure (CHF).

Aerobic training such as walking or cycling is the traditional activity prescribed in exercise cardiac rehabilitation (ACSM, 2000; Coats, 1993; Fletcher et al., 2001; Pollock et al., 2000). However, resistance training is the preferred method to increase muscle strength which is essential in order to maintain and improve the patients functional ability (Pu et al., 2001; Sparling et al., 1990), help improve their independence and confidence (ACSM, 2000) and assist in prevention of osteoporosis, obesity and other chronic conditions (Pollock et al., 2000). Nevertheless, health professionals do not commonly prescribe this form of exercise to their patients mainly because of a concern for increases in wall tension due to elevation in blood pressure and afterload.

Intensity is a fundamental factor in training prescription for both aerobic and resistance exercise. Exercising at 40-85% peak aerobic capacity (VO_2) is the recommended intensity for aerobic training in cardiac patients (Fletcher et al., 2001; Moraes et al., 1999). An acceptable method to determine peak VO_2 in cardiac patients is the Balke incremental treadmill test where walking speed remains constant and slope is increased every 2 minutes by 2.5% (or every 1 minute by 1%) (Hanson, 1984). The Balke test is recommended for cardiac patients since the elevation in workload is moderate and therefore considered safe even for patients with severe left ventricular dysfunction (Conn et al., 1982; Hanson, 1984; Nieman, 2003).

The maximal strength (MS) test has previously been used to assess maximal strength of healthy middle aged (Hurley et al., 1988), elderly (Shaw et al., 1995) and coronary artery disease subjects (Featherstone et al., 1993; Ghilarducci et al., 1989). Although several studies with CHF patients have used the MS test as a maximal strength indicator (Maiorana et al., 2000; Meyer et al., 1999; Pu et al., 2001) there is lack of data on the hemodynamic responses of these patients to MS tests compared to aerobic exercise.

Therefore to help investigate the responses of CHF patients to resistance exercises, the purpose of this study was to compare the physiological responses of CHF patients to both a Balke incremental treadmill test and a MS test.

METHODS

Subjects

Fifteen men age 57±10.2yrs who were diagnosed with left ventricular systolic dysfunction (EF, 34.7±7.3) volunteered to participate in the study (subject's clinical characteristics are shown in Table 1). The study protocol was approved by both the Human Research Ethics Committee Southern Cross University (ECN-02-110) and John Flynn Private Hospital (02/08). Prior to participation, all subjects were informed about the nature of the study and signed an informed consent.

Subjects who had the following contraindications were excluded from the research: smokers, those with locomotor disability, ventricular arrhythmias, unstable angina or who had a resting diastolic pressure above 95mmHg, a resting systolic pressure above 160mmHg or uncontrolled congestive heart failure, acute myocarditis, severe valvular stenosis and persons who were unable to consent for themselves.

Study protocol

All subjects completed a medical examination to identify secondary conditions or contraindications for exclusion. Subjects performed a Balke incremental treadmill test (TRACMASTER, JAS Fitness System 210AC/R, USA) where walking speed remained constant ($3 km·h^{-1}$) whilst the grade was increased by 2.5 percent every two minutes (Hanson, 1984). Patients were instructed not to eat or drink caffeine for at least two hours before the tests.

Table 1. Subject's (n = 15) clinical characteristics. Data are means (±SD).

Age (yrs)	57.0 (10.2)
Weight (kg)	91.3 (12.1)
Height (m)	1.78 (.08)
Resting HR (bpm)	69.8 (12.5)
Resting SBP (mmHg)	110.5 (19.7)
Resting DBP (mmHg)	70.9 (8.5)
Peak VO_2 ($ml·kg^{-1}·min^{-1}$)	14.6 (2.3)
EF (%)	34.7 (7.3)
Medication *	
Beta-blockers:	
Carvedilol	11
Bicor	2
Atenolol	1
Inderal	1
Diuretics	5
ACE inhibitors	12
Ant cholesterol	10
Digoxin	3
Anti arrhythmic	4
Pain reliefs	7
Diabetes medications	3

* number of subjects on each medication, some subjects on multiple medications.
Abbreviations: HR = heart rate, SBP = systolic blood pressure, DBP = diastolic blood pressure, EF = ejection fraction, ACE = angiotensin-converting enzymes.

During the test the subjects HR was monitored by 12 lead electrocardiograph (ECG). Brachial blood pressure was measured by auscultation every 2 minutes. Aerobic capacity (VO_2) was determined by gas analysis (Medgraphics, cardio2 and CPX/D System Operators Manual – Utilizing Breezeex Software, 142090-001, Revia, MN, providing data every 15 seconds). Calibration against three standard alpha gases was conducted prior to each test. Myocardial oxygen consumption which is represented by the RPP was calculated via the equation SBPxHR/100 (where SBP, systolic blood pressure, HR, heart rate) (Fletcher et al., 2001; Siegelova et al., 2000). HR, systolic and diastolic blood pressure and RPP at peak and at 80% of peak VO_2 during the incremental test were reported. Criteria to terminate the test followed the recommendation of the American Association of Cardiovascular and Pulmonary Rehabilitation and the American College of Sport Medicine (AACVPR, 1999; ACSM, 2000).

Approximately one week after the incremental test patients performed a MS test which was defined as the heaviest weight a subject could lift (between one and four repetitions) with a proper lifting technique and normal breathing pattern, and without compensatory movements (Levinger et al., in press). Two days prior to the MS test subjects completed a familiarization session with the resistance equipment and were instructed in correct lifting techniques. A correct breathing technique was explained and practiced in order to avoid a Valsalva maneuver. Tests were performed on resistance exercise equipment (Schwinn 780 SI Strength System) for chest press, leg press, lateral pull-down, triceps extension, knee extension, upright row, seated row and biceps curl following 5-10 minutes of warm-up on a treadmill and a stretching regime. MS was determined using a similar protocol to Hagerman et al. (2000), which included 1 set of 10 repetitions followed by gradually increasing weights (by 10-20%, the amount of weight added and the number of repetitions were depended on the perception of effort of the patient) until failure. The resting periods between sets were 60-90 seconds and between exercises 90-150 seconds. Blood pressure (auscultation) and HR (polar watch) were monitored immediately after each exercise.

Data Analysis

Paired T-tests was used to assess hemodynamic (HR, SBP, DBP and RPP) differences between the peak Balke incremental test and the MS test and to assess differences between hemodynamics during exercise at 80% of peak VO_2 and MS test.

A repeated measure ANOVA was used to assess RPP differences between each of the resistance exercises using Bonferroni method adjustment. The results are reported as means ±standard deviation (SD). A 0.05 level of significance was used to determine statistical differences (SPSS 11.0 for Windows).

RESULTS

The common criteria for terminating the incremental test were falls of SBP≥10mmHg with increased workload (N=3), ST depression>2 mm (N=4) and no increase of VO_2 despite an increase of workload (N=4). Four subjects had their test terminated at RPE of 15 (upper most criterion which was approved by the Ethics committee). The mean RPE and the mean respiratory exchange ratio (RER) at termination of the test were 13.4±1.3 and 0.91±0.1 respectively. Additionally, no injuries, muscle soreness or other local adverse effect were recorded during and for 24 hours after the MS tests.

Table 2. Comparison between HR, SBP, DBP and RPP at peak Balke incremental walking test and immediately after eight resistance exercises (average) MS test. Data are means (±SD).

	Peak incremental test	MS test
HR (bpm)	106.3 (18.9)	86.9 (12.7) *
SBP (mmHg)	134.1 (22.2)	118.3 (15.1)*
DBP (mmHg)	72.0 (7.6)	74.0 (8.7)
RPP	138.7 (26.1)	101.5 (16.2) *

* Indicates significant $p < 0.01$ between tests.
Abbreviations: HR = heart rate, SBP = systolic blood pressure, DBP = diastolic blood pressure, RPP = rate pressure product (HR×SBP/100).

HR, SBP and RPP were significantly lower during the MS test than during both the peak Balke incremental test and walking at 80% of peak VO_2 (Table 2 and 3). DBP did not differ between the two tests ($p>0.05$).

Table 3. Comparison between HR, SBP, DBP and RPP at 80% of peak VO_2 during Balke incremental walking test and immediately after eight resistance exercises (average) MS test. Data are means (±SD).

	80% of peak VO_2	MS test
HR (bpm)	96.9 (12.8)	86.9 (12.7)*
SBP (mmHg)	131.8 (23.1)	118.3 (15.1)*
DBP (mmHg)	73.2 (10.5)	74.0 (8.7)
RPP	126.4 (28.1)	101.5 (16.2)*

* Indicates significant $p<0.01$ between tests.
Abbreviations: HR = heart rate, SBP = systolic blood pressure, DBP = diastolic blood pressure, RPP = rate pressure product (HR×SBP/100).

No significant RPP differences were found between upper and lower body resistance exercises ($p > 0.05$). The only significantly RPP difference was during the biceps curl and triceps extension exercises (105±17.7 vs. 95.1±19.6, $p < 0.05$) and the seated row and triceps extension exercises (106.4±20.3 vs. 95.1±19.6, $p < 0.05$).

DISCUSSION

The important findings of the study were that the physiological responses as determined by HR, BP and RPP changes, were less severe during a MS test than those reported during an incremental Balke treadmill test. Therefore, MS tests may be an acceptable method to assess the maximal strength of patients with moderate heart failure.

The rationale for assessing maximal strength are, firstly, to assist in determining an accurate exercise intensity; secondly, to monitor objective changes in skeletal muscle strength (Shaw et al., 1995). The resistance training intensity level that has been recommended for cardiac patients is between 50-70% of MS (10-15 repetitions) (ACSM, 2000). However, there is a lack of information on the hemodynamic responses to maximal strength tests in CHF patients which makes it difficult to determine the resistance training intensity for this population.

Previous studies have demonstrated that RPP during intensities of 80%-100% of maximal strength exercise is lower than during submaximal aerobic treadmill exercise in patients with coronary artery disease (Crozier et al., 1989; Featherstone et al., 1993; Ghilarducci et al., 1989; Kelemen et al., 1986). The RPP responses to the incremental and strength tests reported in this study for CHF patients are in accordance with those reported for other cardiac patients. The RPP at peak VO_2 during the incremental tests (Table 2) and during exercising at 80% of peak VO_2 (Table 3) were significantly higher than during the strength tests. However, in our study both lower HR and SBP contributed to the decrease in RPP where in other studies the lower RPP was mainly due to lower HR (Featherstone et al., 1993; Kelemen et al., 1986). The HR and SBP attained in the present study compared to Featherstone et al. (1993) and Kelemen et al. (1986) was much lower in intensity as depicted by the difference in the end point of the incremental test. Patients in the current study may not have reached their true peak VO_2 as the incremental tests were terminated at submaximal exercise levels, evident by the relatively low RER and RPE. However, since a significant lower HR, SBP and RPP were observed between the treadmill and strength tests, it may emphasis that during peak aerobic exercise the differences between aerobic and resistance exercises is even greater than reported. In addition, Meyer et al. (1999) and King et al. (2000) reported a substantial increase in both HR and SBP during exercise at 60% and 80% of MS compared to rest values, however, they did not examine these responses in comparison to responses during aerobic exercise. McKelvie et al. (1995) used direct measurement of blood pressure to examine the different responses of 10 CHF patients to both aerobic (cycling at 70% of peak VO_2) and resistance (leg press at 70% of one repetition maximum) exercises. They reported no significant difference in SBP between the two tests however both HR and RPP were significantly lower during the leg press exercise compared to cycling.

Our finding supports Ghilarducci et al. (1989) Stewart et al. (1989) and Karlsdottir et al. (2002) who reported similar hemodynamic responses during weight lifting using upper and lower extremities but is in contrast to Vander et al. (1986) and MacDougall et al. (1985) who reported higher RPP during lower extremities exercises. The MS tests provoked similar RPP responses between most exercises. The only RPP difference was observed during biceps curl exercise and triceps extension and during seated row and triceps extension. Although both triceps extension and biceps curl exercises were performed with the subjects standing, the RPP during biceps curl was significantly higher. The higher RPP during biceps curl may be as a result of postural muscles of the trunk activated to stabilize the body during the test. Additionally, the higher RPP may indicate that some of the patients exhibited an increase in the intrathorathic pressure. The higher RPP during seated row may be as a result of the activation of larger muscle groups of the back (especially latissimus dorsi) compared to a smaller muscle of the triceps (triceps brachii).

In contrast to Featherstone et al. (1993) who reported a decrease in DBP during treadmill tests and Haslam et al. (1988) who reported an increase in DBP during strength exercises, we did not find any change in DBP during the incremental test nor during the MS test ($p > 0.05$). These data support the findings of Sparling et al (1990) who reported no change in DBP during resistance training. Others studies reported an increase in the DBP compared to resting values during strength testing (Karlsdottir et al., 2002; King et al., 2000; Squires et al., 1991). An increase in DBP of between 1 to 13 mmHg during resistance exercise (Stralow et al., 1993), with the combination of lower HR has been suggested to improve coronary artery filling at a higher perfusion pressure (McCartney, 1998; 1999).

In light of our results the MS test may be a suitable method to assess the patient's maximal strength prior to entering a rehabilitation program. Also it appears that resistance training may be a suitable training method for CHF patients.

In view of the current study results, there are three limitations that should be acknowledged. Firstly, our results may not be generalized to the entire CHF population, as the number of subjects is relatively small. Secondly, we measured the blood pressure noninvasively immediately after each strength test. An indirect measurement of systolic blood pressure (by auscultation) may be up to 13% lower during rest compared to direct measurements (by brachial artery catheter) and up to 35% lower immediately after weight lifting (Wiecek et al., 1990) which may suggest that the actually SBP during the weight lifting and immediately after is higher than reported. However, it is important to note that most studies which examined the BP responses during acute and chronic exercises used the auscultation technique (Delagardelle et al., 1999; Featherstone et al., 1993; Karlsdottir et al., 2002; Maiorana et al., 2000; Stewart et al., 1998; Stralow et al., 1993). Nevertheless, further studies employing direct blood pressure measurements are needed in order to clarify this issue. Thirdly, due to equipment limitations, MS was defined as the heaviest weight subject could lift between 1 to 4 repetitions (approximately 85-95% of one repetition maximum). Further studies are needed in order to assess the safety of resistance exercise of varying intensities including one repetition maximum.

CONCLUSIONS

The physiological responses, as measured by HR, BP and RPP, to a maximal strength test in this study were lower compared to both peak incremental test and compared to walking at 80% of peak VO_2. Also the finding suggests that MS tests may be an acceptable method to assess the maximal strength of patients with moderate heart failure.

ACKNOWLEDGMENTS

This study was partly funded by Roche Products Pty Ltd NSW, Australia. The authors wish to thank Elite Fitness Group, Australia for contributing the resistance equipment. Ms. Karen Gosper for her assistance in recruiting the subjects and Mrs. Debbie Humphreys for her assistance during the testing procedures.

REFERENCES

AACVPR, (1999) *Guidelines for Cardiac Rehabilitation and Secondary Prevention Program: American Association of Cardiovascular and Pulmonary Rehabilitation.* 3rd edition. Champaign, IL: Human Kinetics.

ACSM, (2000) *American College of Sports Medicine (ACSM's) Guidelines for Exercise Testing and Prescription.* 6th edition. Baltimore: Lippincott Williams and Wilkins.

Coats, A.J.S. (1993) Exercise rehabilitation in chronic heart failure. *Journal of The American College of Cardiology* **22**, 172A-177A.

Conn, E.H., Williams, R.S. and Wallace, A.G. (1982) Exercise responses before and after physical conditioning in patients with severely depressed left ventricular function. *The American Journal of Cardiology* **49**, 296-300.

Crozier, L.E., Holly, R.G. and Amsterdam, E.A. (1989) Effects of high resistance training in coronary artery disease. *The American Journal of Cardiology* **64**, 866-870.

De Sousa, E., Veksler, V., Bigard, X., Mateo, P. and Ventura-Clapier, R. (2000) Heart failure affects mitochondrial but not myofibrillar intrinsic properties of skeletal muscle. *Circulation* **102**, 1844-1854.

Delagardelle, C., Feiereisen, P., Krecke, R., Essamri, B. and Beissel, J. (1999) Objective effects of a 6 months' endurance and strength training program in outpatients with congestive heart failure. *Medicine and Science in Sports and Exercise* **31**, 1102-1107.

Delp, M.D., Duan, C., Mattson, J.P. and Musch, T.I. (1997) Changes in skeletal muscle biochemistry and histology relative to fiber type in rats with heart failure. *Journal of Applied Physiology* **83**, 1291-1299.

Featherstone, J.F., Holly, R.G. and Amsterdam, E.A. (1993) Physiologic responses to weight lifting in coronary artery disease. *The American Journal of Cardiology* **71**, 287-292.

Fletcher, G.F., Balady, G., Amsterdam, E.A., Chaitman, B., Eckel, R., Fleg, J.L., Froelicher, V.F., Leon, A. S., Pina, I.L., Rodney, R., Simons-Morton, D.G., Williams, M.A., and Bazzarre, T. (2001) Exercise standards for testing and training: a statement for healthcare professionals from the American Heart Association. *Circulation* **104**, 1694-1740.

Ghilarducci, L.E.C., Holly, R.G. and Amsterdam, E.A. (1989) Effects of high resistance training in coronary artery disease. *The American Journal of Cardiology* **64**, 866-870.

Hagerman, F.C., Walsh, S.J., Staron, R.S., Hikida, R.S., Gilders, R.M., Murray, T.F., Toma, K., and Ragg, K.E. (2000) Effects of high-intensity resistance training on untrained older men. I. Strength, cardiovascular, and metabolic responses. *Biological Sciences* **55A**, B336-B346.

Hanson, P. (1984) Clinical Exercise Training. In: S*port Medicine*. Ed: Strauss, R. Philadelphia, PA: W.B. Saunders Company. 13-40.

Haslam, D.R.S., McCartney, N., McKelvie, R.S. and MacDougall, J.D. (1988) Direct measurements of arterial blood pressure during formal weightlifting in cardiac patients. *Journal of Cardiopulmonary Rehabilitation* **8**, 213-225.

Hurley, B.F., Hagberg, J.M., Goldberg, A.P., Seals, D.R., Ehsani, A.A., Brennan, R.E., and Holloszy, J.O. (1988) Resistive training can reduce coronary risk factors without altering VO2max or percent body fat. *Medicine and Science in Sports and Exercise* **20**, 150-154.

Karlsdottir, A.E., Foster, C., Porcari, J.P., Palmer-McLean, K., White-Kube, R. and Backes, R.C. (2002) Hemodynamic responses during aerobic and resistance exercise. *Journal of Cardiopulmonary Rehabilitation* **22**, 170-177.

Kelemen, M.H., Stewart, K.J., Gillilan, R.E., Ewart, C.E., Valenti, S.A., Manley, J.D., and Kelemen, M.D. (1986) Circuit weight training in cardiac patients. Journal of The American College of Cardiology **7**, 38-42.

King, L.M., Dracup, K.A., Fonarow, G.C. and Woo, M.A. (2000) The hemodynamic effects of isotonic exercise using hand-held weights in patients with heart failure. *Journal of Heart and Lung Transplantation* **19**, 1209-1218.

Levinger, I., Roger, B., Cody, V.D., Linton, I. and Davie, A. Resistance training for chronic heart failure patients on beta blocker medications. *International Journal of Cardiology* In press.

MacDougall, J.D., Tuxen, D., Sale, D.G., Moroz, J.R., Sutton, J. R. (1985) Arterial blood pressure response to heavy resistance exercise. *Journal of Applied Physiology* **58**, 785-790.

Maiorana, A., O'Driscoll, G., Cheetham, C., Collis, J., Goodman, C., Rankin, S., Taylor, R., and Green, D. (2000) Combined aerobic and resistance exercise training improves functional capacity and strength in CHF. *Journal of Applied Physiology* **88**, 1565-1570.

Mancini, D.M., Walter, G., Reichek, N., Lenkinski, R., McCully, K.K., Mullen, J.L., and Wilson, J.R. (1992) Contribution of skeletal muscle atrophy to exercise intolerance and altered muscle metabolism in heart failure. *Circulation* **85**, 1364-1373.

McCartney, N. (1998) Role of resistance training in heart disease. *Medicine and Science in Sports and Exercise* **30**, S396-402.

McCartney, N. (1999) Acute responses to resistance training. *Medicine and Science in Sports and Exercise* **31**, 31-37.

McKelvie, R.S., McCartney, N., Tomlinson, C., Bauer, R. and MacDougall, J.D. (1995) Comparison of hemodynamic responses to cycling and resistance exercise in congestive heart failure secondary to ischemic cardiomyopathy. *The American Journal of Cardiology* **76**, 977-999.

Meyer, K., Hajric, R., Westbrook, S., Haag-Wildi, S., Holtkamp, R., Leyk, D., and Schnellbacher, K. (1999) Hemodynamic responses during leg press exercise in patients with chronic congestive heart failure. *The American Journal of Cardiology* **83**, 1537-1543.

Moraes, R.S. and Ribeiro, J.P. (1999) Heart disease. In:. *Exercise in Rehabilitation Medicine*. Eds: Frontera, W.R., Dawson, D.M., Slovik, D.M. Champaign, IL: Human Kinetics. 175-192.

Nieman, D.C. (2003) *Exercise Testing and Prescription: A Health-Related Approach*. 5th edition. NY: McGraw-Hill Companies, Inc.

Pollock, M.L., Franklin, B.A., Balady, G.J., Chaitman, B., Fleg, J.L., Fletcher, B., Limacher, M., Pina, I.L., Stein, R.A., Williams, M., and Bazzarre, T. (2000) Resistance exercise in individuals with and without cardiovascular disease: benefits, rationale, and prescription an advisory from the committee on exercise, rehabilitation, and prevention, council on clinical cardiology, *American Heart Association. Circulation* **101**, 828-833.

Pollock, M.L., Gaesser, G.A., Butcher, J.D., Despres, J.P., Dishman, R.K., Franklin, B.A., and Garber, C.E. (1998) The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adult (American College of Sport Medicine). *Medicine and Science in Sports and Exercise* **30**, 975-991.

Pu, C.T., Johnson, M.T., Forman, D.E., Hausdorff, J.M., Roubenoff, R., Foldvari, M., Fielding, R.A., and Singh, M.A.F. (2001) Randomized trail of progressive resistance training to counteract the myopathy of chronic heart failure. *Journal of Applied Physiology* **90**, 2341-2350.

Shaw, C.E., MaCully, K.K. and Posner, J.D. (1995) Injuries during the one repetition maximum assessment in the elderly. *Journal of Cardiopulmonary Rehabilitation* **15**, 283-287.

Siegelova, J., Fiser, B., Dusek, J., Placheta, Z., Cornelissen, G. and Halberg, K. (2000) Circadian variability of rate-pressure product in essential hypertension with enalapril therapy. *Scripta Medica* **73**, 67-75.

Simonini, A., Long, C.S., Dudly, G.A., Yue, P., McElhinny, J. and Massie, B.M. (1996) Heart failure in rats causes changes in skeletal muscle morphology and gene expression that are not explained by reduced activity. *Circulation Research* **79**, 128-136.

Sparling, P.B., Cantwell, J.D., Dolan, C.M. and Niederman, R.K. (1990) Strength training in a cardiac rehabilitation program: a six-month follow-up. *Archives of Physiology and Medicine Rehabilitation* **71**, 148-152.

Squires, R.W., Muri, A.J., Anderson, L.J., Allison, T.G., Miller, T.D. and Gau, G.T. (1991) Weight training during phase II (early outpatient) cardiac rehabilitation. *Journal of Cardiopulmonary Rehabilitation* **11**, 360-364.

Stewart, K.J. (1989) Resistive training effects on strength and cardiovascular endurance in cardiac and coronary prone patients. *Medicine and Science in Sports and Exercise* **21**, 678-682.

Stewart, K.J., McFarland, L.D., Weinhofer, J.J., Cottrell, E., Brown, C.S. and Shapiro, E.P. (1998) Safety and efficacy of weight training soon after acute myocardial infarction. *Journal of Cardiopulmonary Rehabilitation* **18**, 37-44.

Stralow, C.R., Ball, T.E. and Looney, M. (1993) Acute cardiovascular response of patients with coronary disease to dynamic variable resistance exercise of different intensities. *Journal of Cardiopulmonary Rehabilitation* **13**, 255-263.

Sullivan, M.J., Duscha, B.D., Klitgaard, H., Kraus, W.E., Cobb, F.R. and Saltin, B. (1997) Altered expression of myosin heavy chain in human skeletal muscle in chronic heart failure. *Medicine and Science in Sports and Exercise* **29**, 860-866.

Vander, L.B., Franklin, B.A., Wrisley, D. and Rubenfire, M. (1986) Acute cardiovascular responses to nautilus exercise in cardiac patients: implications for exercise training. *Annals of Sports Medicine* **2**, 165-169.

Wiecek, E.M., McCartney, N. and McKelvie, R.S. (1990) Comparison of direct and indirect measures of systemic arterial pressure during weightlifting in coronary artery disease. *American Journal of Cardiology* **66**, 1065-1069.

AUTHORS BIOGRAPHY

Itamar LEVINGER
Employment
Master student in Southern Cross University, Lismore, NSW, Australia.
Degree
BEd
Research interests
Exercise physiology and rehabilitation programs of special populations with special interest in cardiac patients.
E-mail: ilevin10@scu.edu.au

Roger BRONKS
Employment
Head of Exercise Science and Sport Management School, Southern Cross University, Lismore, NSW, Australia.
Degree
PhD
Research interests
Applied anatomy and rehabilitation programs for special populations.
E-mail: rbronks@scu.edu.au

David V. CODY
Employment
Cardiologist in John Flynn Private Hospital, Gold Coast, QLD, Australia.
Degree
PhD
Research interests
Rehabilitation and exercise physiology in cardiac patients with focus on chronic heart failure.

Ian LINTON
Employment
Cardiologist in John Flynn Private Hospital, Gold Coast, QLD, Australia.
Degree
MD
Research interests
Rehabilitation strategies for cardiac patients in general and these with chronic heart failure in particular.

Allan DAVIE
Employment
Senior lecturer in the School of Exercise Science and Sport Management, Southern Cross University, Lismore, NSW, Australia.
Degree
PhD
Research interests
Exercise physiology, muscle responses and adaptation during training and rehabilitation in athletes and special populations.
E-mail: adavie@scu.edu.au

KEY POINTS

- The physiological responses of CHF patients to maximal strength test were less severe than those reported during a walking incremental test.
- There were similar hemodynamic responses during upper and lower resistance exercises.
- Maximal strength test appears to be an acceptable method to assess the maximal strength of patients with moderate CHF.

✉ **Itamar Levinger**
Southern Cross University. PO Box 157 Lismore NSW 2480 Australia.