CARDIOVASCULAR ADAPTATIONS

by M. Doug McGuff, M.D.

The function of your cardiovascular system is to pump oxygen and nutrient rich blood to the tissues of your body. The "cardio" in cardiovascular refers to your heart. Your heart's contribution is its pumping action that moves the blood through your body. The "vascular" in cardiovascular refers to your blood vessels, which include the arterial system that carries blood from your heart to your organs and the venous system which carries blood back from your organs to your heart. Your blood vessels can change their caliber and thus affect the resistance that your heart has to pump against, which in turn affects how much blood can be pushed forward with each beat of your heart.

Your heart produces bloodflow or *cardiac output* through its heart rate and its stroke volume (how much blood pushed forward per heartbeat). If you need to increase your cardiac output, you can do so by increasing your heart rate, increasing your stroke volume or both. You can also increase your cardiac output by dilating the arteries and decreasing the resistance (called *peripheral vascular resistance*) that the heart must pump against. One last way to increase cardiac output is to increase the amount of blood returning to your heart. Your heart functions like a sump pump. This means whatever volume is brought into the pump is the volume that is pushed out of the pump. Thus, if you increase the amount of blood returning to the heart from the venous side of the circulation, you will increase the amount of blood pumped out of the heart (this is called *Starling's Law of the Heart*).

Now that you have a basic understanding of cardiovascular physiology you can now see the various ways that we may enhance our cardiovascular functioning by increasing our cardiac output. We can strengthen our heart so that it pumps more with each beat (increased stroke volume). We can increase our heart rate in times of demand. We can have more plentiful and more pliable blood vessels so that our heart has to pump against less resistance (lower systemic vascular resistance-lower blood pressure). Or we can enhance venous return to the heart.

Traditional aerobic exercise has been known to produce many of these positive adaptations. Most of this has been demonstrated using a test called V02max which is a measure of oxygen utilization during exercise. Scientists have found that V02max tracks cardiac output and thus have used it as an indirect measure of how effectively a particular exercise was at stimulating the cardiovascular system. The use of this test is one of the main reasons that resistance training was felt to be a poor stimulator of the cardiovascular system. It seems that at the very high levels of exertion seen in resistance training V02max falls off. Rather than assuming something may be flawed with the test, scientists assumed that cardiac output must fall during weight training. They reasoned that the contracting and engorged muscles squeezed the blood vessels and increased peripheral vascular resistance and trapped venous blood which inhibited cardiac return. In addition to decreasing cardiac output, many thought resistance training dangerously raised blood pressure. Despite saying that it had little effect on the heart, most experts said resistance training was unsafe for those with heart disease because it placed too great a strain on the heart.

I had always maintained that resistance training had a profound effect on the cardiovascular system. The reason the muscles pump up and become engorged is directly due to increased blood flow from increased cardiac output. When you perform hard exercise, adrenaline causes your arteries in your gut to constrict and the arteries in your muscles to dilate. This diverts blood flow to your working muscles and is why your mom told you not to swim right

after eating. The dilation of these arteries causes a decrease in peripheral vascular resistance, which allows an increase in cardiac output. Furthermore, the "pump" that occurs in the muscles along with the squeezing actions of the working muscles actually "milks" blood from the venous system towards the heart. Veins, unlike arteries, have very little tone. They act as passive conduits of blood. The major way that blood in the veins is made to move back towards the heart is by the milking action of the working muscles. The more forcefully a muscle contracts, the more profound will be this milking action. This increased blood return to the heart creates a need for an increased cardiac output because of Starling's Law of the Heart. Even more important, is the fact that coronary artery blood flow is dependent on blood return to the heart, which increases the blood leaving the aorta. As blood leaves the aorta it rushes forward. During diastole (the relaxation phase of the heartbeat) aortic blood washes back into the coronary arteries. An increase in cardiac output as a result of increased venous return causes a rise in the *end diastolic bloodflow* in the aorta. Coronary artery blood flow is proportionate to end diastolic bloodflow. I mention this because of some observations I have made in several of my clients. I have some clients with known coronary artery narrowing. Their coronary artery disease causes them to have *angina*, which is heart pain due to poor coronary artery blood flow. Despite exercising these subjects at a relatively high intensity, we have never had any episodes of angina. These same clients will get angina when walking uphill or exercising on a treadmill or bike. My theory (and it is still only a theory) is that walking does not produce intense enough muscular contractions to stimulate increased venous return which would augment end diastolic blood flow and coronary artery bloodflow. I believe resistance training increases venous return and coronary blood flow so that these subjects can tolerate a much higher intensity of exercise without experiencing angina. Despite many experts' concern that resistance training may not be safe for those with coronary artery disease, I believe we may come to find that it is the only form of exercise safe for these people. Furthermore, since steady state exercise increases demands on the heart without a significant enhancement of venous return and coronary blood flow...it may be the most dangerous form of exercise for cardiac rehab patients. Currently, most cardiac rehab programs emphasize the development of "aerobic conditioning" before any resistance training is considered. In the future, I believe we should not consider exposing these people to aerobic exercise until they have developed an adequate base of strength conditioning through proper resistance training. Below are listings of research articles that I feel support my conclusions.

1. Hemodynamic responses during leg press exercise in patients with chronic congestive heart failure. Myer K and Hajric R, et.al. *Am J Cardiol*. 1999 Jun 1; 83(11):1537-43.

In this study the subjects had a catheter in place that was actually inserted into the central circulation so that cardiovascular changes could be measured directly. Subjects were stable patients and patients with congestive heart failure. Measurements were taken while they performed resistance training on a leg press machine. Both groups showed beneficial changes in cardiac parameters, but this was more pronounced in the stable group of patients. More important than the differences between the groups was the actual effect on the cardiovascular system. The findings confirmed the assertions that I made above. There were significant increases in heart rate, diastolic pulmonary artery pressure (a measure of venous return and end diastolic pressure and thus, indirectly a measure of coronary blood flow), as well as an increase in cardiac index (which is cardiac output per unit of body surface area). Even at the highest workloads, they found a *decrease* in systemic vascular resistance which resulted in an increased cardiac index and enhanced left ventricular function. This study shows that I was correct. All of the explanations for why V02max might fall off during resistance training are not occurring. Resistance training does in fact produce dramatic beneficial cardiovascular changes.

2. Resistance trained athletes using or not using steroids compared to runners: effects on cardiorespiratory variables, body composition and plasma lipids. Yeater R, Reed C, et. al. *Br J Sports Med* 1996 Mar;30(1):11-4.

Many experts have done studies to show that resistance training causes unfavorable changes in cardiovascular parameters and lipid profiles. This perpetuated the myth that "weight training is bad for your heart". Studies that supported this notion never tried to factor the contribution that steroid use may have had to the data. This study sought to control for this factor. It seems that the steroid users were the ones with the negative cardiac effects and they were skewing the data. The conclusion of this study? "Resistance training in the absence of steroid use results in the same positive effects on cardiac dimensions, diastolic function, and blood lipids as aerobic training".

3. Strength training normalizes resting blood pressure in 65- to 73-year-old men and women with high normal blood pressure. Martel GF, et. al. *J Am Geriatr Soc* 1999 Oct;47(10):1215-21.

We have commonly heard warnings from medical experts that weight training may cause elevation of the blood pressure and should be avoided in those with high or borderline high blood pressure. This study followed 21 subjects, all over age 65 with borderline hypertension. The subjects performed whole-body weight training involving 7 exercises. The study was carried out for 6 months. All of the study subjects showed improvement in their blood pressure. To quote the researchers' conclusion... "the changes in resting BP noted in the present study represent a shift from the high normal category to the normal category".

4. Progressive resistance exercise and resting blood pressure: A meta-analysis of randomized controlled trials. Kelley GA, Kelley KS *Hypertension* 2000 Mar;35(3):838-43.

A meta-analysis is an attempt to look at <u>every</u> quality study that addresses a particular subject. The pooling of data that occurs in a meta-analysis provides greater numbers of study subjects which gives more power to the study's conclusions. With thousands of study subjects, the probability that the study's results where due to chance alone become almost non-existent. The criteria to make it into this meta-analysis included: (1) trials that included a randomized nonexercise control group; (2) progressive resistance exercise as the only intervention; (3) adult humans; (4) journal articles, dissertations, and masters theses published in English-language literature; (5) studies published between January 1996 and December 1998; (6) resting systolic and/or diastolic blood pressure assessed; and (7) training studies lasting a minimum of 4 weeks. These criteria assured that only the best objective studies were included. The conclusion of this meta-analysis is "progressive resistance exercise is efficacious for reducing resting systolic and diastolic blood pressure in adults".

5. Physiological response to circuit weight training in borderline hypertensive subjects. Harris KA, Holly RG. *Med Sci Sports Exerc* 1987 Jun;19(3):246-52.

Even though the above studies have shown that resistance training improves blood pressure in people with borderline hypertension, many are still concerned that blood pressure may rise to dangerous levels *during* the workout itself. This study followed 10 experimental and 16 control subjects through 9 weeks of resistance training. Marked increases in strength were noted, but more importantly they concluded... "circuit weight training does not exacerbate resting or *exercise* blood pressure".

6. Blood pressure in resistance-trained athletes. Colliander EB, Tesch PA *Can J Sport Sci* 1988 Mar;13(1):31-4.

Despite the evidence presented in the above studies showing that resistance training actually improves blood pressure, many still argue that these are not necessarily meaningful studies because the studies are only weeks or months long. It has been suggested that it is long term weight training, as performed by athletes or bodybuilders that may cause problems. In this study *long-term* bodybuilders were compared against age-matched controls. Blood pressure was measured both at rest and during exercise. The conclusion of the study is... "intense long-term strength training, as performed by bodybuilders, does not constitute a potential cardiovascular risk factor.

7. Effects of long term resistance training on left ventricular morphology. Haykowsky MJ, et. al. *Can J Cardiol* 2000 Jan;16(1):35-8.

"Weight training will enlarge your heart", how many times have you heard this statement? I've heard it so many times that I've lost count. I've even heard it from fellow physicians. The condition they refer to is actually called *IHSS* (*ischemic hypertrophic subaortic stenosis*). The enlarged ventricle does not allow blood to flow out of the aorta and fatal heart dysrhythmias can occur. This condition can be seen in athletes, particularly strength athletes. My own suspicion is that the condition is probably related to steroid abuse in those with a congenital abnormality. This recent study addresses the question of whether long term resistance training causes heart enlargement. Echocardiograms were performed on 21 elite male powerlifters and 10 control subjects. None of the powerlifters showed any sign of heart enlargement. Powerlifters carry out the type of training that would be most likely to cause heart enlargement. Despite this fact the study concludes... "contrary to common beliefs, long term resistance training as performed by elite male power-lifters does not alter LV morphology".

I hope I have shown with good scientific evidence that resistance training is the best way to train your cardiovascular system. All the changes that are produced by traditional cardiovascular exercise (which was previously thought not to occur with resistance training) are actually produced to an even greater degree with high intensity resistance training. Furthermore, all the potential dangers to the cardiovascular system such as increased blood pressure, and heart strain that have been attributed to resistance training actually turns out to be nothing more than a myth. In my opinion, resistance training is actually protective to the heart during exertion. Increased blood return to the heart increases coronary artery blood flow. This allows for higher levels of exertion with less risk of coronary ischemia. For people with coronary artery disease, resistance training may prove to be the safest and most effective way to improve their cardiovascular health. As it turns out this is not just my opinion. There are numerous research studies that show that resistance training is safe for those with coronary artery disease and even in those who have recently had heart attacks. The cardiovascular improvements have been equal or better than that seen with traditional cardiac rehabilitation. Below is a list of articles that show that resistance training is safe and beneficial for those with cardiac disease.

1. Role of resistance training in heart disease. McCartney N. *Med Sci Sports Exerc* 1988 Oct; 30(10 Suppl):S396-402.

2. Usefulness of weightlifting training in improving strength and maximal power output in coronary disease. McCartney N, et.al. *Am J Cardiol* 1991 May 1;67(11):939-45.

3. Circuit weight training in cardiac patients: determining optimal workloads for safety and energy expenditure. DeGroot DW, et.al. *J Cardiopulm Rehabil* 1998 Mar-Apr;18(2):145-52.

4. Resistive training effects on strength and cardiovascular endurance in cardiac and coronary prone patients. Stewart KJ. *Med Sci Sports Exerc* 1989 Dec;21(6):678-82.

5. Circuit weight training in cardiac patients. Keleman MH, et. al. *J Am Coll Cardiol* 1986 Jan;7(1):38-42.

6. Strength training early after myocardial infarction. Daub WD, et. al. *J Cardiopulm Rehabil* 1996 Mar-Apr;16(2):100-8.

7. The role of resistance training in patients with cardiac disease. McCartney N, McKelvie RS. *J Cardiovasc Risk* 1996 Apr;3(2):160-6.

8. Resistive exercise training in cardiac rehabilitation. An update. Verrill DE, Ribisl PM. *Sports Med* 1996 May;21(5):347-83.

9. Effects of weight training on muscle strength and exercise capacity in patients after myocardial infarction. Yamasaki H, et.al. *J Cardiol* 1995 Dec;26(6):341-7.

10. Safety and efficacy of weight training soon after acute myocardial infarction. Stewart KJ, et. al. *J Cardiopulm Rehabil* 1998 Jan-Feb;18(1):37-44.

11. Effects of high-intensity strength training on quality-of-life parameters in cardiac rehabilitation patients. Beniamini Y, et.al. *Am J Cardiol* 1997 Oct 1;80(7):841-6.

12. High-intensity strength training of patients enrolled in an outpatient cardiac rehabilitation program. Beniamini Y, et.al. *J Cardiopulm Rehabil* 1999 Jan-Feb;19(1):8-17.

The abstracts of the above articles can be pulled up from the National Library of Medicine at http://www.ncbi.nlm.nih.gov.