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I am submitting herewith a thesis written by Sharon Marie Boon entitled "Orthostatic Tolerance in Males Who Perform Chronic Resistance Training Versus Controls." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree Master of Science, with a major in Human Performance and Sports Studies.

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ORTHOSTATIC TOLERANCE IN MALES WHO PERFORM CHRONIC RESISTANCE TRAINING VERSUS CONTROLS

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Abstract

The purpose of this study was to investigate whether individuals who performed chronic resistance training (CRT) had an increased lower body negative pressure (LBNP) tolerance over controls (CON), and to determine if there was a correlation between lean body mass (LBM) and LBNP tolerance index (LTI). Fourteen male subjects were classified as either CRT or CON based on past history of resistance training; this was verified with 5-RM bench press and leg extension tests. The subjects attended 3 sessions. On the first session, maximal oxygen uptake (VO_{2max}) was assessed and the subjects were given an orientation LBNP test. During the second session, the subjects underwent a neck chamber test, another LBNP test and an orientation to strength tests. The final visit consisted of underwater weighing and final strength tests. CRT and CON subjects were not different in age, height, % body fat, VO_{2max}, and maximal HR ($P>0.05$). Significant differences were found between groups in weight, LBM, years of resistance training, 5-RM bench press and leg extension, and resting forearm and leg circumferences (FC and LC, respectively; $P<0.05$). LBNP data showed no between-group differences in systolic, diastolic or mean arterial blood pressures (SBP, DBP and MABP, respectively), forearm blood flow (FBF), forearm vascular resistance (FVR) and LC at rest or 25, 50, 75 or 100% $LBNP_{max}$. There were, however, significant decreases in HR, SBP, MABP, and FBF for both groups as presyncopy approached. Significant differences were found between CRT and CON for $LBNP_{max}$ ($p=0.005$) and LTI ($p=0.003$). LBM did not significantly correlate with LTI ($p=0.0785$). Multiple regression analyses indicated LBM + LC ($p=0.0112$) and LBM + 5-RM leg extension ($p=0.0113$) to be significant,

however slope (beta) was -0.11. and -0.016, respectively. CRT did not alter carotid sinus mechanoreceptor function; ΔR-R was non-significantly different between CRT and CON. In conclusion, individuals who perform chronic resistance training have an improved LBNP tolerance.

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Chapter 1

Introduction

Mechanoreceptors are important in the maintenance of mean arterial blood pressure (MABP) during orthostatic stress in individuals restricted to bedrest (22, 60, 107), those individuals required to stand motionless for extended periods of time (26, 78), pilots who experience increased gravitational forces during flight maneuvers (8, 32, 91), and astronauts, who experience fluid shifts during lift-off (22), weightlessness (14), and re-entry (14, 61). Those individuals with reduced orthostatic tolerance, defined as a decrease in the ability to maintain consciousness during standing or blood volume shifts toward the legs (74, 78), are prone to syncope (fainting) during these rapid changes in body position and blood volume shifts (8, 14, 22, 26, 32, 62, 64, 91). Therefore, it is possible that mechanoreceptor function is impaired in individuals with low orthostatic tolerance.

Mechanoreceptors play an important role in short- (immediate) and long-term blood pressure regulation (44, 68, 78). There are two sets of mechanoreceptors within the human body: high pressure and low pressure. The high pressure (arterial) mechanoreceptors are located on the arterial side of the circulatory system and include the carotid bodies, the aortic mechanoreceptors, and the mechanoreceptors found in all major arteries (44). The low pressure (cardiopulmonary) mechanoreceptors are located on the venous side of circulation (right atrium and lungs) and assist in the return of blood to the heart by eliciting changes in total peripheral resistance (TPR) and venous compliance (14, 74, 94). Both types of mechanoreceptors are important in orthostatic tolerance.

Several techniques have been developed to test mechanoreceptor responsiveness. The techniques pertinent to this study are neck suction/pressure and lower body negative pressure. A neck suction chamber stimulates the arterial mechanoreceptors causing a reflex reduction in heart rate. A neck pressure chamber does the opposite, depressing the arterial mechanoreceptors and elevating heart rate. Low pressure mechanoreceptors can be inhibited using a lower body negative pressure (LBNP) chamber (37, 58, 62, 94). When body fluids accumulate in the lower extremities, venous return is decreased, central venous pressure is decreased, and finally cardiac output is decreased. As a result, the low pressure mechanoreceptors become inhibited (26, 94).

Exercise appears to affect the functioning of both the high-pressure and low-pressure mechanoreceptors. The effects of short-term resistance training on orthostatic tolerance have been studied by several investigators. Tesch et al. (91) and Epperson et al. (32) had subjects perform a whole-body resistance training protocol for 11 and 12 weeks, respectively, and found that centrifuge tolerance improved significantly following training. Lightfoot et al. (64) examined responses to lower body negative pressure (LBNP) and found that 12 weeks of whole-body resistance training improved orthostatic tolerance over non-trained controls. In contrast, Tatro et al. (90) and Balldin et al. (8) found no difference between resistance trained subjects and controls following either a 19-week lower-body-only training regimen or an 11-week abdominal training protocol, respectively.

In contrast to the volume of research done utilizing short-term and chronic endurance-trained subjects (9, 19, 26, 37, 42, 47, 53, 61, 62, 66, 74, 86, 88), few studies have examined individuals who perform chronic resistance

training. Results of three studies (64, 86, 88) indicated that bodybuilders or powerlifters have an increased orthostatic tolerance beyond what was seen in the 11- and 12-week resistance training studies mentioned above. Smith and Raven (88) and Smith et al. (86) took subjects to a LBNP of -50 mmHg and noted limited changes in heart rate and blood pressure in individuals who had undergone chronic resistance training, while untrained controls showed significantly greater changes in both parameters. Lightfoot et al. (64) tested subjects to pressures where pre-syncope signs occurred (maximal LBNP tolerance). At the maximum negative pressure tolerance, individuals who participated in chronic resistance training were able to tolerate significantly greater negative pressures (mean ≈ -90 mmHg; $p < 0.05$) than untrained (≈ -75 mmHg) or 12-week resistance trained (≈ -80 mmHg). Neck chamber results indicated that the chronic resistance trained group had a reduced baroreceptor sensitivity, as evidenced by smaller changes in heart rate above an estimated carotid sinus pressure of 120 mmHg when compared to the 12-week resistance trained or control group (64). Since Lightfoot et al. (64) only tested five chronically resistance trained individuals, which may not be truly representative of this type of individual, more research is needed to determine whether their results were typical of all individuals participating in chronic resistance training.

Researchers have suggested that decreased venous compliance leads to increased orthostatic tolerance (12, 24, 72). Compliance is defined by Guyton and Hall (44) as "the total quantity of blood that can be stored in a given portion of the circulation" (p.171). Muscle mass and calf cross sectional area (CSA) have been shown to affect venous compliance; muscle exhibits tension at rest which limits venous expansion, and reduces the capacity of the veins

to accommodate a greater blood volume (12, 13, 24, 72). Convertino et al. (24) found a strong inverse relationship between calf muscle cross sectional area and venous compliance following 30 days of bed rest ($r= -0.72$, $p<0.05$). Buckey et al. (12) noted that venous compliance increased and calf circumference decreased over a 10-day period of head-down tilt ($p<0.05$). These data suggest that individuals with smaller muscle masses and calf cross-sectional areas would tend to have an increased level of venous compliance and would tend to exhibit greater venous pooling during simulated or actual orthostatism (12, 23, 24). In contrast, a person who performs resistance training would typically increase muscle cross-sectional area (hypertrophy)(2, 8) and show a greater tendency for increased tolerance to orthostatic stress (12, 23, 32, 64, 86, 88, 90, 91). Endurance athletes, due to their activity and relatively low body fat compared to controls, tend to have a small cross-sectional calf area, and exhibit a greater level of venous pooling (23). Strength and sprint-trained athletes, on the other hand, typically display more muscle hypertrophy and exhibit less venous pooling (12, 23, 32, 64, 86, 88, 91). Subjects who participated in a chronic resistance training program showed a trend toward a larger resting leg circumference compared to those who completed a 12-week resistance training program and untrained subjects (64).

Lawler et al. (58) measured the leg muscle mass and LBNP tolerance up to -60 mmHg in individuals of varying levels of fitness. They found no difference in leg mass (determined by DEXA) or VO_{2max} in subjects able to complete the LBNP protocol to -60 mmHg for 5 minutes and those who could not. However, determination of leg muscle mass alone may not be sufficient to establish a relationship between orthostatic tolerance and lean muscle (fat free) mass. Tatro et al. (90) observed that only performing resistance training

exercises for the lower body did not affect orthostatic tolerance. In contrast, several other studies indicated that whole-body resistance training was able to increase orthostatic tolerance (32, 64, 88, 91). More specifically, the strength of the biceps and abdominals ($r = 0.746$, $p<0.01$) were found to be most highly correlated with the ability to withstand greater levels of LBNP (32). The addition of bench press (chest) and leg press strength raised this correlation to $r = 0.783$. Epperson et al. (32) also noted that tolerance was increased after only 4 weeks of resistance training. At this time, the subjects had not yet increased significantly the amount of weight being lifted nor had circumference measurements changed (32), though this may have been sufficient time for muscle tension to increase. If whole-body resistance training is important for improving orthostatic tolerance, as previous studies suggest, perhaps fat free mass, and the increase in resting muscle tension provided by resistance training, are important factors affecting LBNP tolerance.

Therefore, the purpose of this study was to determine if subjects who participate in chronic resistance training exhibit a higher tolerance to simulated venous pooling (LBNP) when compared to non-resistance-trained individuals.

Specifically, the following hypotheses were tested:

1) There will be a difference between maximal LBNP tolerance in individuals undertaking chronic resistance training and controls.

2) There will be a significant correlation between fat free mass and maximal LBNP tolerance.

Chapter 2

Review of Literature

Physiology of Orthostatic Tolerance

Numerous space physiology studies (69) have been performed over the years since man first left the earth's atmosphere in 1961 (99). While these studies of actual and simulated microgravity have shown man to be capable of sustained living in space, changes do occur to the body which cause the space-traveler to experience complications upon return to Earth and its gravity (13, 14, 38, 39, 46, 84, 89, 95, 105). These changes include alterations in bone structure and density (10, 16-18, 43, 51, 52, 54, 57, 84, 96, 103, 104), muscle atrophy and structural alterations (2, 7, 15, 27, 31, 33, 45, 48, 55, 76, 85, 92, 106), decreased immune function (4, 5, 81), and, most importantly for this study, orthostatic intolerance (4, 5, 13, 14, 20, 46, 59, 73, 80, 93, 95).

A person exposed to microgravity experiences a redistribution of fluid from the lower body toward the torso and head (13, 36, 59), as well as a reduction in blood volume (59, 77), which may cause an ischemic condition (52) that could result in some of the observed alterations in bone and muscle composition. The opposite event of having a gravity-induced fluid shift toward the lower body occurs when a person goes from a prone or sitting position to a standing position ("orthostatism")(74, 78). When this occurs, mean arterial blood pressure (MABP) will either be maintained within acceptable limits or drop to levels that impair normal physiological function (14, 78). When MABP (cardiac output x total peripheral resistance) is maintained, this maintenance is initiated by mechanoreceptors sensing the change in blood pressure and triggering a subsequent increase in cardiac

output (heart rate x stroke volume) and/or increase in total peripheral resistance (TPR)(13, 14, 19, 74). If MABP drops, the mechanoreflex would be judged as unsuccessful in compensating for the fluid shifts by insufficiently increasing cardiac output and/or TPR (68, 78). In the situation where the mechanoreceptors have not compensated adequately, the person becomes presyncopal and, if immediate steps are not taken to equalize blood distribution, the person may lose consciousness (syncope) because venous return to the heart has been compromised (14, 21, 26, 74).

The Frank-Starling mechanism of the heart states that the heart will, within its physiological limits, pump out what is pumped in (44). The greater the volume of blood entering the heart during diastole, the greater the stretch on the heart muscle, and the greater the contraction of the ventricles to eject the blood into the pulmonary arteries and aorta (44, 107). If there is a decrease in venous return, the amount of blood returning to the heart, the result is a decreased cardiac output. The amount of stretch on the sino-atrial (SA) node caused by the returning blood helps regulate heart rate, i.e. increased stretch of the SA node will increase heart rate through sympathetic stimulation (44). However, under normal, non-stressful conditions, venous return is the determining factor of cardiac output (44).

Blood Volume

When a person undergoes orthostatism, blood pools in the legs (13, 14). However, if the individual is exposed to microgravity, actual or simulated, blood is distributed more evenly throughout the body (12, 13, 22, 38, 39, 59, 77), and there is almost immediate decrease in plasma volume (14, 80). Fitts et al. (88) suggested that the decreased plasma volume might be from an increase in

the extracellular fluid (interstitial areas). Convertino et al. (24) reported that humans undergoing 30-days of head-down tilt did not have a significant change in intracellular water content. Leach et al. (59), in a more extensive study, found that while total body water content did not change in astronauts after a maximum of 14 days of spaceflight, there was a decrease in extracellular fluid volume. Plasma volume decreased almost immediately upon exposure to microgravity, 17% within the first 21 hours, and remained diminished until landing. It appears that in space or during microgravity conditions, plasma volume decreases as the human body acclimates to the new environment (59).

Following spaceflight, astronauts have a reduction in blood volume of about 500 ml (14), along with a reduced orthostatic tolerance (14, 38, 39). Eckberg et al. (30) noted that individuals with a similar blood volume reduction resulting from something other than real or simulated spaceflight exhibit an increase (26, 66) rather than a reduction (26, 30) in orthostatic tolerance (26, 30). Elevations in blood volume can be seen following endurance training (50, 80, 86), which tends to coincide with reduced orthostatic tolerance (50, 66, 74, 80, 83, 86). The mechanism for this is not yet understood.

In another study, Buckey et al. (14) noted that 9 to 14 days of spaceflight resulted in a 9% reduction in blood volume, and a decreased orthostatic tolerance, as evaluated by a 10-minute stand test. During pre-flight testing, all 14 astronauts were able to complete a 10-minute stand, while post-flight testing found only 5 were able to finish. The stand test consisted of each astronaut resting in a supine position for baseline measurements, after which he/she was instructed to stand without actively contracting the leg muscles

(14), an action which would alter responses to the test by increasing venous return through muscle pump action (87).

Laboratory Methods of Testing Orthostatic Tolerance

While it may be difficult to quantify the magnitude of stress tolerated with a stand test (14, 70), it is the most clinically relevant test for astronauts (14). Fortunately, there are other quantifiable means of simulating venous pooling. One technique utilizes a centrifuge with the subject seated in a slightly reclined position, facing the center of the machine. The rate of spinning determines the magnitude of gravitational stress (8, 32, 47, 91). As mentioned in Chapter 1, LBNP chambers are used to cause venous pooling (37, 65, 68, 78), and neck chambers are utilized to determine arterial mechanoreceptor sensitivity (9, 22, 29, 30, 35, 38, 71, 75).

Factors Affecting Orthostatic Tolerance

Past research has focused on finding ways to predict orthostatic tolerance as well as on how exercise training affects tolerance. Blomqvist and Stone (as reported in Rowell (78)) identified several factors that might lead to a decreased orthostatic tolerance. These factors included an increased venous capacitance (compliance), reduced cardiopulmonary and arterial mechano-receptor sensitivity, and a reduction in skeletal muscle tone. Others have also noted how physical characteristics and fitness-related variables relate to orthostatic tolerance (9, 19, 26, 32, 47, 62, 64, 66, 74, 86, 88, 90, 91).

Venous Compliance

Convertino et al. (26) found that venous capacitance can be influential in orthostatic tolerance, reporting a strong correlation (r = 0.989) using the fluid accumulation index, blood volume and leg compliance index (fluid accumulation index/cumulative stress index[1]) to predict LBNP tolerance. Fluid accumulation, or venous pooling, is affected by venous compliance, i.e., the ability of the vessel to expand to hold more blood (12, 24, 78). During LBNP protocols, leg circumference can be monitored to determine if there is a change in leg volume, i.e., an index of venous pooling (102). Following bed rest, subjects have exhibited a significantly reduced orthostatic tolerance along with decreases in resting calf volume and circumference and increase venous compliance (12, 24). Smith and Raven (88), in testing endurance-trained, resistance-trained and untrained individuals, found that the untrained subjects had significantly less change in leg volume (% change) at -50 mmHg LBNP than either trained group; they did not specify how long the endurance- and resistance-trained subjects had been training. Results from another study (62) found that individuals participating in 10 weeks of endurance training had similar changes in leg circumference during LBNP compared to untrained individuals. While Hudson et al. (50) also noted no significant differences between endurance trained and untrained individuals at -40 and -50 mmHg LBNP, the endurance-trained individuals did have significantly larger calf volume increases at -8, -16 and -32 mmHg. Following 19 weeks of lower-body-only resistance training, subjects in Tatro et al. (90) had no difference in leg circumference at -60 mmHg LBNP when compared to

[1] cumulative stress index = Σ (negative pressure x length of stage)

pre-training values. Lightfoot et al. (64) noted that while 10 weeks of whole-body resistance training did not alter leg circumference changes at maximal LBNP tolerance, the individuals who had been resistance training for at least 4 years did have a trend toward a greater increase in leg circumference ($p = 0.10$).

Smith et al. (86) found that endurance-trained individuals were unable to increase peripheral vascular resistance (PVR) during simulated orthostatism, and had a greater decrease in MABP versus untrained controls. Heart rate decreased for both endurance-trained and untrained groups while stroke volume and cardiac output remained relatively unchanged, suggesting that it was peripheral resistance, not cardiac output, that could not be maintained following chronic endurance training (86). In a recent study on astronauts following 9 to 14 days of spaceflight, Buckey and colleagues (14) also found that inability to maintain total peripheral resistance appeared to be the major factor contributing to orthostatic intolerance.

Cardiopulmonary Mechanoreceptor Sensitivity

A reduction in cardiopulmonary (low pressure) mechanoreceptor sensitivity can be measured through blood pressure and heart rate responses to LBNP. During LBNP of a magnitude less than -20 mmHg, the arterial mechanoreceptors are unaffected while cardiopulmonary receptors are inhibited; at negative pressures exceeding -20 mmHg, both cardiopulmonary and arterial mechanoreceptors are inhibited (68). It is with these latter pressures that cardiac output decreases (the cardiac depressor reflex)(68), which decreases central venous (right atrium) pressure (CVP). CVP must be maintained at a pressure of -3 to -5 mmHg, the pressure of the surrounding

chest cavity (44). If CVP increases to 0 mmHg, cardiac output is severely compromised (68). Under stressful situations, i.e., orthostatic stress, CVP can decrease to this level as venous return is compromised (44, 78). Cardiac output will not be maintained unless CVP is restored by muscle pump reactivation (having person contract leg and abdominal muscles)(70) or by having the person assume a horizontal position (removal of hydrostatic gradient)(53, 62). In the case of LBNP, CVP may be restored by complete removal of negative pressure (26, 37, 62, 64, 88, 94).

While studies have shown significant within-group decreases in systolic blood pressure at maximal LBNP tolerance ($LBNP_{max}$) compared to baseline (62, 64, 66, 90), submaximal LBNP tests have shown there to be little between-group differences with endurance-trained and control subjects (50, 86, 88). However, when compared to individuals participating in resistance training, the endurance-trained and control subjects had significantly lower systolic blood pressures either up to or at -50 mmHg during submaximal LBNP (86, 88). Following 12 weeks of resistance training, Lightfoot et al. (64) found no significant difference in systolic blood pressure between baseline and $LBNP_{max}$ in the resistance-trained and control subjects, as well as in individuals who had been chronically resistance-trained. However, resistance training did significantly decrease the amount of change in systolic blood pressure at $LBNP_{max}$ for the individuals who had undergone 12 weeks of resistance training (64). This study also found that 12 weeks of resistance training had a significant impact on the magnitude of change in MABP, and that individuals performing chronic resistance training actually increased MABP from baseline to $LBNP_{max}$ (64).

Changes in heart rate and diastolic blood pressure have typically been shown to decrease at a similar rate across all trained/untrained groups at given pressures up to -50 mmHg (26, 50, 62, 64, 90). Forearm blood flow (FBF) also decreased across all groups (50, 62, 64, 82), and has been shown to be significantly different from baseline to -50 mmHg (62, 64, 82). Several studies (50, 64, 82, 90) have found forearm vascular resistance (FVR = MABP/FBF) to be the same between endurance-trained (50, 82, 90) or resistance-trained (64) and untrained subjects and from baseline to $LBNP_{max}$. However, Lightfoot et al. (62) found FVR to be increased significantly at $LBNP_{max}$ in both control subjects and in subjects before and after 10 weeks of endurance training. Seals and Chase (82) found a significant within-group decrease in FVR following 30 weeks of endurance training. Alterations in CVP, mechanoreceptor sensitivity or vascular responsiveness may be responsible for this decrease (82). These data suggest a possible change in the cardiopulmonary mechanoreceptor control following long-term endurance training (41, 82).

Arterial Mechanoreceptor Sensitivity

Arterial mechanoreceptors sensitivity can be tested utilizing neck chambers (29). These chambers "fool" the arterial mechanoreceptors into detecting an instantaneous change in blood pressure. Neck suction has an inhibitory effect on the carotid mechanoreceptor, eliciting an increase in the R-R interval; neck pressure decreases the R-R intervals by decreasing carotid pressure (67). The maximum slope of the change in R-R (ΔR-R) interval/ carotid sinus pressure curve serves as an indicator of the sensitivity of the carotid mechanoreceptors (66, 75, 82).

Table 1. Carotid mechanoreflex slopes from previous studies

Study	n	Group	Max. slope	*P*
Ludwig & Convertino (66)	14	varied	4.36 ± 2.27	r = 0.363
Reiling & Seals (75)	12	ET	1.1 ± 0.3	p = 0.09
	12	UNT	3.1± 1.1	
Fiocchi et al. (35)	24	CET	7.3 ± 0.8	
Barney et al. (9)	11	CET	4.00 ± 0.39	p<0.05
	9	UNT	2.53 ± 0.28	
Tatro & Convertino (90)	8	pre-RT	5.4 ± 1.3	p = 0.0141
	8	post-RT	6.6 ± 1.6	
Eckberg & Fritsch (30)	6	pre-HDT	4.5 ± 0.4	p = 0.11
	6	post-HDT	3.6 ± 0.07	
Convertino et al. (22)	16	pre-DT	4.0 ± 0.05	p = 0.00008
	16	post-DT	2.8 ± 0.4	
Fritsch et al. (38)	11	pre-SPF	5.0 ± 1.0	
	11	landing	3.4 ± 0.5	<0.05 vs. pre-SPF
	12	2 d REC	3.6 ± 0.6	<0.05 vs. pre-SPF
	12	3 d REC	3.9 ± 0.6	<0.05 vs. pre-SPF
	12	8-10 d REC	3.9 ± 0.6	<0.05 vs. pre-SPF

UNT = untrained; ET = endurance trained; RT = resistance trained; CET = chronic endurance trained; HDT = 6° head down tilt; DT = 2 weeks detraining; SPF = spaceflight; d REC = days of recovery following landing

Studies that have tested endurance athletes, either chronically trained or after 10 to 30 weeks of training, have found varying results in carotid mechanoreceptor sensitivity versus untrained controls (9, 62, 75, 82). Table 1 lists maximum carotid mechanoreceptor slopes from several studies. Training studies, lasting 10 (62) and 30 weeks (82), have found no difference within or between the endurance-trained and control subjects before and after training. When individuals who had been chronically endurance trained were tested, there has been either a trend or a significant difference in sensitivity slope when compared to untrained (9, 75). Barney et al. (9) noted a significantly higher reflex slope in high fit individuals (defined as VO_{2max} >

53 ml/kg/min)($p<0.05$) in comparison to sedentary controls, while Reiling and Seals (75) found a trend ($p=0.09$) in mechanoreceptor sensitivity in subjects that had been chronically endurance-trained. These same studies also found an increased R-R interval (i.e. lower HR) versus controls at -40 mmHg ($p<0.05$)(9, 75) and -25 mmHg ($p<0.01$)(75) of neck suction. While it appears that undertaking a chronic endurance training program may alter arterial mechanoreceptor sensitivity, it is questionable whether this change is related to VO_{2max} (9, 35, 50, 74). Fiocchi et al. (35) found no correlation between VO_{2max} and carotid mechanoreceptor sensitivity ($r = 0.05$), while Barney et al. (9) noted a stronger relationship ($r = 0.48$). In a review paper, Raven and Pawelczyk (74) concluded, after testing a much wider range of fitness levels than previous studies, that sensitivity of the carotid mechanoreceptors was directly related to VO_{2max}.

The results are conflicting regarding the effect of resistance training on arterial mechanoreceptor sensitivity. While 19 weeks of lower-body-only resistance training produced a significant difference in maximum slope ($p = 0.0141$; see Table 1)(90), 12 weeks of full-body resistance training failed to produce a similar effect (64). Subjects who had been chronically resistance-trained had a less steep, though non-significantly different, slope in comparison to the untrained subjects (54)(64).

Carotid mechanoreceptor sensitivity appears to decrease following detraining, bed rest or spaceflight (see Table 1)(18, 20, 24, 31). Following either detraining or 6° head-down tilt (a method of simulating microgravity effects on the body (36)), studies have found a significant decline in the ΔR-R slope (25, 38). Fritsch et al. (38) noted arterial mechanoreceptor sensitivity decreased upon landing following 4 and 5 days of spaceflight. Convertino et al. (25)

found significant decrease in ΔR-R slope following 2 weeks of exercise detraining ($p<0.05$). Two other studies did not elicit changes in maximum slope following 10 (30) or 30 days (22) of head-down tilt, although the 10-day study did exhibit a trend ($p = 0.11$)(30).

Skeletal Muscle Tension

Blomqvist and Stone (78) have also identified loss of skeletal muscle tone to be significantly linked to a decrease in orthostatic tolerance. It has be shown previously that spaceflight results in a decrease in orthostatic tolerance (14, 22, 38, 39) as well as decrease in muscle mass (3, 6, 11, 31, 85, 97). These data suggest that an increased muscle mass improves tolerance. Table 2 shows results of detraining and training studies on various lean mass related variables. In studies where orthostatic tolerance improved following resistance training (29, 53, 79), circumference measurements typically did not

TABLE 2. Effects of training and detraining on body mass, leg volume and circumference

Study	Treatment	Measurement	Before	After	P
Detraining					
Convertino et al. (22)	30 d HDT	calf vol (cm^3)	1682 ± 83	1512 ± 76	<0.05
		calf CSA (cm^2)	74.2 ± 3.6	70.6 ± 3.4	<0.05
Buckey et al. (14)	9-14 d SPF	leg vol (cm^3)	9643 ± 340.8	8885 ± 298.9	<0.01
Training					
Epperson et al. (32)	12 wk RT	body mass (kg)	69.6 ± 2.7	71.2 ± 2.9	<0.01
		% body fat	16.7	13.9	<0.01
		est. lean mass	58	61.3	
Tesch et al. (91)	11 wk RT	capillary density (cap/mm^2)	352 ± 42	264 ±18	NS

Data shown as mean ± SE; HDT = 6° head down tilt; SPF = spaceflight; CSA = cross sectional area; RT = resistance training

change (32, 64), except at the chest and biceps (32). This lack of circumference change may have been due to the loss of body fat; Epperson et al. (32) noted a 16.8% drop in body fat over their 12-week resistance training program. It may also be that 12 weeks is not long enough for resistance-trained muscles to display significant amounts of hypertrophy (56). However, following 19 weeks of lower-body-only resistance training, there was a significant increase (21 ± 5 %, $p = 0.0014$) in average muscle fiber size (90). It may not be essential to have a significant increase in muscle fiber size or strength for there to be an increase in muscle tension and an improvement in orthostatic tolerance; improved centrifuge tolerance has been noted without strength or circumference changes, following as little as 4 weeks of full-body resistance training (32). However, increases in muscle size may continue to improve orthostatic tolerance (12, 22). Along with the correlation between biceps and abdominal strength and centrifuge tolerance (32) mentioned in Chapter 1, isometric knee flexor (quadriceps) endurance has also been correlated to centrifuge tolerance (32).

In a recent study, Lawler et al. (58) assessed leg lean mass of individuals to see if there was a correlation with LBNP tolerance. Subjects were placed in a high lean mass or low lean mass category, with different defining parameters for men and women. Using LBNP up to -60 mmHg, the researchers found that the subjects able to complete the protocol averaged leg muscle masses of 20.3 ± 1.1 kg for men and 13.7 ± 1.6 kg for women. Subjects unable to finish the protocol had slightly (nonsignificantly) higher leg muscles masses (22.3 ± 1.2 kg and 14.9 ± 1.1 for men and women, respectively). They concluded that leg mass and LBNP tolerance were not related (58).

While resistance training influences muscle mass, it also affects capillary density (56). Following 11 weeks of resistance training, Tesch et al. (91) noted a slightly reduced capillary density concurrent with improved centrifuge tolerance (see Table 2). Kraemer et al. (56) note that the type of resistance training protocol influences changes in capillary density. Body builders have actually shown an increase in capillary density (capillaries per mm^2) compared to untrained subjects, possibly due the need for lactate removal. Powerlifters, however, have shown a decrease in capillary density versus untrained subjects (56). The difference between the bodybuilder and powerlifter training protocols is the duration of each set (the number of repetitions per set). Bodybuilders lift less weight for more repetitions, while powerlifters lift more weight fewer times (56, 98). While capillary density data appears to be equivocal regarding resistance training, several studies cited in Saltin et al. (79) agree that endurance training does increase capillary density. A change in capillary density following training may influence the amount of venous pooling a person can tolerate.

Physical Characteristics and Fitness Variables

Fitness variables have also been studied in an attempt to find variables that correlate with orthostatic tolerance. It appears that age (26), weight (26), and percent body fat (26, 91), do not correlate well, while research regarding height is conflicting. Ludwig et al. (66) noted that subjects of shorter stature (mean = 173 cm) were able to tolerate higher levels of LBNP than taller subjects. Lightfoot et al. (65) noted no such effect ($p = 0.14$).

It also appears that there is no correlation between LBNP tolerance and VO_{2max} (26, 50, 65), even though VO_{2max} appears to affect carotid sinus

mechanoreceptor sensitivity (9, 74). Convertino et al. (26) specifically investigated whether VO_{2max} and LBNP tolerance were correlated. Across a range of values (range 27.6-70.2 ml/kg/min, mean 45.2 ± 2.7 ml/kg/min), VO_{2max} only contributed 1.1% to the prediction of orthostatic tolerance ($r = 0.049$, $p = 0.85$). Hudson et al. (50) and Tesch et al. (91) also found no relationship between VO_{2max} and orthostatic tolerance. Hudson et al. (50) recruited female subjects and placed them into a trained or untrained category based on VO_{2max} (>55 ml/kg/min vs. <45 ml/kg/min, respectively). At -50 mmHg of LBNP, the trained group showed a non-significant trend toward reduced LBNP tolerance, which, if taken to greater negative pressures, might establish a significant relationship between training state and orthostatic tolerance. In contrast to this, Fortney et al. (37) showed that older men (59-73 years) who engaged in chronic endurance training demonstrated a much stronger relationship between VO_{2max} and orthostatic tolerance, indicating the mechanism of blood pressure regulation may change with age. While LBNP tolerance does not appear to be related to VO_{2max}, it may be a factor associated with a decreased orthostatic tolerance (74).

Summary

In summary, research has failed to demonstrate a significant training effect on LBNP tolerance following longitudinal endurance training of up to 30 weeks (26, 50, 63, 82, 91). There may be a cumulative effect of endurance training, requiring greater than 30 weeks of training to alter cardiopulmonary and arterial mechanoreceptor sensitivity (40, 74). Carotid sinus mechano-receptors appear to be reset following endurance training, resulting in an increased maximum slope (9, 35). Studies on the short- and long-term effects

of resistance training have demonstrated that LBNP and centrifuge tolerance can increase if a whole-body program is undertaken (32, 64, 86, 88, 90, 91). Venous compliance and muscle tension appear to be affected most by this type of training protocol (32). Various physical characteristics do not appear to influence orthostatic tolerance (26, 65, 66, 91), with the possible exception of height (66).

Chapter 3

Methods

Subject Recruitment and Selection

Subjects were recruited using flyers posted on the University of North Carolina, Charlotte (UNC-Charlotte) campus and in surrounding fitness facilities. Fourteen males, between the ages of 20 and 30 years, volunteered for this study. To be considered chronically resistance trained, the subject needed to have been on a regular resistance training program 3 or more days per week for at least the past 2 years, with no more than 3 consecutive weeks off in a given year. Seven subjects fit the criteria of being chronically resistance (weight) trained; an equal number of controls were matched for age and aerobic capacity. Chronic training status was verified by having each subject complete a questionnaire on past exercise habits. The control subjects were screened for participation in resistance training programs; if they did any resistance training within the past year, they were not included in this study.

Individuals responding to the flyer were given a thorough explanation of the study over the phone. If the individual was still interested in participating in the study, an initial screening occurred for the purpose of further determination of possible health/medical problems and training status which might exempt the person from the study. If there were no medical restrictions and an appropriate training status, an initial laboratory visit was scheduled. All testing was performed at the Functional Health Laboratory (Room 240) in Belk Gymnasium, the University of North Carolina, Charlotte.

Session 1: Informed Consent, Medical History, VO_{2max} Test, and LBNP Orientation

Informed Consent and Medical History

The subjects arrived in the lab 24 hours post-exercise and alcohol, 4 hours post-prandial, and having had no caffeine that day. They were given another verbal explanation of the study and the risks involved, after which each subject read and signed an informed consent document (see Appendix A) approved by the University of Tennessee at Knoxville and the University of North Carolina at Charlotte Institutional Review Boards. Each subject was encouraged to ask questions and was given a copy of the informed consent document. Furthermore, subjects were encouraged to ask questions throughout all testing procedures. After signing the informed consent document, each subject completed an exercise and medical history form (see Appendix B). Contraindications to testing included the following: past history of cardiovascular disease (including peripheral vascular disease), unexplained or frequent fainting, hemorrhoids, past extensive internal injuries, varicose veins, hypertension, asthma or other lung problems, diabetes mellitus, or Addison's disease[2]. Finally, because of the experimental testing, the subjects were asked, both verbally and on the medical history form, if they were currently taking any respiratory medications. Any subjects who were identified as taking respiratory medications were excluded from the study.

[2] Two potential subjects were excluded due to contraindications to testing. One was borderline hypertensive, the other had frequent PVCs at rest.

Test for Maximal Oxygen Uptake

Following completion of the informed consent document and medical history, subjects were weighed on a physician's scale and had their height measured to the nearest quarter inch. A more thorough explanation of the VO_{2max} test protocol was given. Following the test explanation and after answering any questions from the subject, a warm-up was performed on the treadmill (Quinton Medtrack ST65; Bothell, WA) until heart rate (HR) reached 150 ± 5 beats/minute as read by ECG (Quinton Q4500; Bothell, WA). When heart rate (HR) reached 150 ± 5 beats/minute, the treadmill was stopped, and the subject had headgear (holding mouthpiece and valve in place) and nose clip fitted. The treadmill was then restarted at the predetermined speed, and grade increased to 1% after the first minute; at consecutive minutes, the grade was increased by 2%[3]. When the subject felt he could not complete another full stage, the option of a .5 or 1% grade increase was given in attempt to ensure maximal effort[4].

During the treadmill test, expired gas samples were analyzed for O_2 and CO_2 by a metabolic cart using Ametek analyzers and flow meter (CD-3A Carbon Dioxide Analyzer with Sensor P-61B; Oxygen Analyzer S-3A/I with Sensor N-22M; R-1 flow meter; Pittsburgh, PA). Metabolic calculations were conducted simultaneously by a custom computer program (LabVIEW 4.0; National Instruments, Austin, TX) on a Macintosh Quadra 650 (Cupertino, CA). Subjects tested after 15 May 1999 had the expired gases analyzed by a Physio-Dyne metabolic cart (Quogue, NY), with a Gateway 2000 4DX2-50V computer (San Diego, CA) maintaining the data. Both systems were

[3] One subject requested a 1% grade change throughout the protocol

[4] Only 3 subjects had the .5 or 1% grade increase at the end of the treadmill test. The plateau in oxygen uptake was not used as a criteria for determining maximal effort for these subjects.

calibrated prior to testing with gravimetrically determined gases and, at the completion of the test, results were averaged over 15 second intervals.

The test was terminated when the subject reached volitional exhaustion and was unable to continue. A fingerprick was made on the subjects' right index finger 1.0 minutes and 3.5 minutes following test completion. Twenty to 25 microliters of blood were placed on a lactate test strip (Boehringer Mannheim Corp., Indianapolis, IN) and analyzed by Accusport lactate analyzer (Boehringer Manneheim Corp., Indianapolis, IN). The Accusport has previously been shown to be an accurate method of determining blood lactate (34). The test was determined to have been maximal if the subject attained an respiratory exchange ratio (RER) of greater than 1.10, had a plateau in oxygen uptake, or had a blood lactate value exceeding 8 mmol/L (28, 49). All subjects reached an RER value above 1.10.

Orientation to Lower Body Negative Pressure Chamber[5]

Following the treadmill test, the subject was placed in a supine position in the LBNP chamber for testing of cardiopulmonary mechanoreceptor function. A bicycle seat and foot rests in this chamber helped keep the subject in position. A rubber tube was secured around the subject's waist, a wooden baffle placed and adjusted so that the subject was sealed into the chamber at the level of his iliac crest, and a kayak skirt secured in position over the baffle. The subject was then asked to tilt his hips (flatten his low back) so that he was as far down on the bicycle seat as possible to prevent movement during the test.

[5] One subject participated in past LBNP testing at UNC-Charlotte and had this orientation test waived.

During LBNP exposures, all subjects were continuously monitored for heart rate using a 12-lead electrocardiogram (Quinton Q4500; Bothell, WA), while systolic and diastolic blood pressure (SBP and DBP, respectively; Colin STBP 780; Colin Med., San Antonio TX) were measured once per minute. Colin automatic blood pressure cuffs has previously been validated (63, 100, 101). Blood pressure measurements were taken more frequently during the last 60 to 90 seconds of the test as the subjects approached presyncope.

Electromyography (EMG) surface electrodes were placed over the left side gastrocnemius and rectus femoris, with a ground electrode on the patella, to verify muscle relaxation. Muscle tension can alter venous blood flow, which may affect LBNP tolerance (87). Subjects were instructed to maintain an EMG reading as close to 0.0 mV as possible, as displayed by a Inner-Tell EMG monitor (American Biotechnology Corp., Ossining NY).

Testing for LBNP tolerance began with a 3 minute baseline period (no pressure), followed by -10 mmHg changes in pressure in 3 minute stages until presyncopal signs occurred. Negative pressure was generated by a dual-vacuum system controlled with an electric rheostat, and pressure monitored with a mercury manometer. HR and BP were recorded every minute, as well as any subjective symptoms. The LBNP test was stopped with the onset of any one of the following objective or subjective presyncopal signs: 1) a decrease in systolic blood pressure >25 mmHg between adjacent readings; 2) a decrease in diastolic blood pressure >15 mmHg between adjacent readings; 3) a decrease in heart rate >15 beats/min; 4) systolic blood pressure falling below 75 mmHg; 5) an increased forearm blood flow; 6) asystole for greater than 3 seconds; or 7) strong subjective symptoms, such as diaphoresis, confusion, or nausea, or subject asked to stop (61, 62, 64). When reached one of these

criteria, testing was terminated, pressure was immediately returned to 0 mmHg and 3 minutes of recovery data were collected.

Tolerance was measured by the LBNP tolerance index (LTI). The LTI was calculated by multiplying the length of time at each level of LBNP by the difference in negative pressure from the last completed stage, and finally summing the products of each stage (65).

Session 2: Neck Chamber Test, LBNP Test, and Orientation to Strength Testing

Test of Arterial Mechanoreceptor Function

Carotid sinus-heart rate mechanoreflex function was tested using a neck chamber, which applies varying pressure and suction to carotid sinus mechanoreceptors within each subject's neck (62). Two chambers were used for this study, one for pressure, the other for suction. The stimulus was created by a dual vacuum system attached to the chamber by a hose. Pressure/suction was regulated by a solenoid valve and monitored with the use of a BP cuff gauge marked in millimeters.

On the day of the test, the subject came to the facility, voided his bladder, and was then weighed. After being placed in a supine position, a flexible lead neck collar (suction) or rubberized collar (pressure) was fitted and a 12-lead electrocardiogram (ECG) applied. The ECG readings (Quinton Q4500; Bothell. WA) were monitored by a computer program (LabVIEW 4.0; Austin, TX). When all equipment was placed, the subject was instructed to inhale and hold his breath while a data acquisition system collected 5 seconds of baseline HR data, then the computer initiated the suction or pressure stimulus. Pressures of approximately -60, -48, -36, -24, -12, +10, +20 and +40

mmHg were used to stimulate the carotid sinus mechanoreceptors. Each level of stimulus was repeated 5 times, with a minimum of 15 seconds between each test. During the stimulus, the computer collected enough data to capture at least 4 QRS complexes. When the pressure was released, the subject was reminded to breathe. Blood pressure was measured during three of the intervals between pressure changes using an automated blood pressure monitor (Colin STBP 780; Colin Med., San Antonio, TX). Systolic blood pressure was recorded for determination of carotid sinus pressure.

Change in R-R interval (ΔR-R) during neck suction/pressure was determined by taking the difference between the third R-R interval during the stimulus and the baseline average. Interval changes during the third R-R interval for each level of stimulus were averaged by a custom computer program (LabVIEW 4.0; National Instruments, Austin, TX) run on a Macintosh 3200 CS (Cupertino, CA) to obtain a mean value. An estimate of carotid sinus pressure was calculated by subtracting chamber pressure from the average systolic blood pressure.

Test of Cardiopulmonary Mechanoreceptor Function

The test for cardiopulmonary mechanoreceptor function was performed immediately following the neck chamber test, following the same protocols as described in the orientation LBNP test. Additionally, leg circumference changes (i.e., an index of venous blood pooling) were measured using a mercury-in-Silastic strain gauge placed at the largest circumference of the subject's right calf. Placement of the strain gauge (distance from the bottom of the patella) was recorded for retesting purposes. Forearm blood flow was monitored using venous occlusion plethysmography

(102). During venous occlusion plethysmography, a pressure cuff was placed at the right wrist and was maintained at a pressure 30-40 mmHg above systolic blood pressure for the duration of the test to prevent arterial and venous blood flow. Pressure was released for 30 seconds approximately every 7 minutes to avoid extreme subject discomfort.

During venous occlusion plethysmography, a second pressure cuff was placed at mid-biceps and was inflated to a pressure of approximately 50 mmHg for 8 seconds, every 30 seconds. The inflation of the biceps cuff allowed arterial blood flow into the arm, but restricted venous blood flow. To measure changes in forearm circumference as a result of restricted venous flow, a mercury-in-Silastic strain gauge was placed at the greatest circumference of the right forearm, and distance of the gauge from the olecranon process of the humerus was noted (102). Both leg and forearm strain gauges were monitored and recorded continuously during LBNP exposure using a data acquisition program and custom software (LabVIEW 4.0; National Instruments, Austin, TX) on an Macintosh 3200 CS (Cupertino, CA).

Criteria for stopping the test were the same as previously indicated in the LBNP orientation. Three minutes of recovery data (HR, BP, FBF, LC) were collected after stopping the test, and then forearm and leg circumferences at the strain gauge sites were measured and recorded. Both strain gauges were calibrated following completion of the test.

MABP was calculated by summing one-third of the systolic pressure and two-thirds of diastolic blood pressure. Forearm vascular resistance (FVR) was calculated by dividing MABP by FBF.

Orientation to Tests for Muscle Strength

Subjects were given an orientation to the leg extension machine and free weight bench press to serve as a learning period for all subjects for subsequent testing. During this orientation, subjects had the leg extension and bench press demonstrated and verbally explained, and were then allowed to perform the movement. The amount of weight used during these trials was recorded for a starting point reference on the actual testing day.

Lower body strength was measured for each subject using a Cybex leg extension machine (Cybex International, Inc., Medway, MA), which isolates the quadriceps. On this machine, the subject was seated with back support; the seat was adjusted forward or backward so that the axis of rotation for the machine and the knee joint were in alignment and the roller pad was adjusted to fit comfortably at the bend in the ankle. Settings were recorded on a data sheet for retest purposes. The subject was asked to perform six repetitions at during each set. If the subject could successfully perform six repetitions, the weight was increased. A minimum of 3 minutes was allotted between sets for adequate recovery. There were four initial learning sets, starting at a weight the subject felt was easy. On subsequent sets, the weight was increased. Weight lifted and repetitions completed were recorded for each set to serve as a reference start point for maximal testing during the third (final) session. The orientation was terminated after the fourth set.

The bench press was used as a measure of upper body strength. An orientation followed similar guidelines as mentioned above for the leg extension. During the lift, one person stood at each end of the Olympic bar to assist with lifting or controlling the bar, if necessary. If the subject could successfully perform six repetitions, the weight was increased. Weight lifted

and repetitions completed were recorded for each set for a referenced starting point for final strength testing. There were four initial learning sets, starting at a weight the subject felt was rather easy. Subjects were again allowed at least 3 minutes of rest after each set. The orientation was terminated at the end of the fourth set.

Session 3: Hydrostatic Weighing and Strength Testing

Hydrostatic Weighing

Underwater weighing was the criterion measure used in this study for estimating body fatness. Each subject had his residual lung volume measured by the helium dilution method (Morgan Benchmark; PK Morgan Instruments, Dallas, TX). For this protocol, the subject sat in a relaxed position and breathed into a closed-circuit chamber until the computer program (MDAS Pulmonary Program 3.06 by Wyvern Software for Morgan Scientific; Dallas, TX) signaled the subject to perform the functional residual capacity (FRC) protocol[6]. A Keydata computer (Walnut, CA) calculated lung volumes (actual and predicted) for the subject. If the actual value was not physiologically reasonable (within 15% of predicted) the test was redone.

Following determination of residual lung volume, the subject entered the hydrostatic tank filled with warm water (95-98°F; 35-37°C). Upon entering the tank, the subject was asked to remove any air bubbles from his shorts/swim trunks, hair, and skin. He was then instructed to sit in the corner of the tank, submerged to his chin and not touch the suspended chair, to obtain the weight of the chair. The subject was then seated on the suspended chair, and instructed to exhale completely while submerging

[6] FRC protocol: 3 normal tidal breaths followed by a maximal inhale and a maximal exhale.

himself completely in the water. While the subject was submerged, the researcher obtained a weight using a Chatillon scale (John Chatillon & Sons, Inc., Kew Gardens, NY). The typical subject performed this maneuver five to six times, or until readings were similar (± 0.15 kg). An average of these similar readings was calculated to represent under water weight.

Relative body fat percentage was found using the following equations[7](1):

(1) Net UWW = gross UWW - UWW of chair, etc.

(2) $$\text{Body Volume (BV)} = \frac{\text{BW (kg)} - [\text{net UWW (kg)} + \text{RV} + \text{GI}]}{\text{water density}}$$

(3) $$\text{Body Density} = \frac{\text{BW (kg)}}{\text{BV}}$$

(4) $$\text{Rel. \%BF} = \frac{495}{\text{BD}} - 450$$

Tests for Muscle Strength

Subjects were asked to perform maximal strength tests on the leg extension and bench press, using the same protocols as the orientation tests. During this session, the subject continued to add weight until no more that 5 repetitions were able to be completed (a 5-RM test). Weight lifted during the orientation session was used as a reference point for starting the tests. The subject typically achieved the 5-RM for each lift in 3 to 6 attempts, with adequate rest (i.e. at least 3 minutes) and stretching between each attempt.

The leg extension machine was set at the previous settings for seat and roller pad. The subject was asked to perform 6 repetitions at a given weight.

[7] BW= body weight; UWW = underwater weight; RV = residual lung volume; GI = gastrointestinal volume, assumed to be 0.1 liters

During each repetition, the subject was instructed to extend the knee, reach full extension and slowly lower the weight. If the subject could successfully perform 6 repetitions, the weight was increased. Weight and reps were recorded for each set. Testing was terminated when the subject could only complete 5 repetitions.

For the bench press, the subject, lying supine on the bench, slowly lowered the weight (Olympic bar with weight plates added), paused, then lifted the bar back to the elevated start position. The subject was not required to touch the bar to his chest, as this can put undue stress on the shoulder joint. Hand-grip width was between shoulder width and elbow width (with shoulder abducted laterally).

Data and Statistical Analysis

The final HR and BP measurement during LBNP were not included in data analysis as they were typically depressed, which can skew the data. HR, systolic blood pressure (SBP), diastolic blood pressure (DBP), forearm blood flow (FBF) and changes in leg circumference (ΔLC) were analyzed at rest, 25, 50, 75 and 100 percent of maximal LBNP tolerance, and at each negative pressure up to -40 mmHg (lowest stage completed of all subjects) by a repeated measures analysis of variance (ANOVA) using SuperANOVA v1.11 (Abacus Concepts Inc., Berkeley CA). Values used at the $\%LBNP_{max}$ were located with information provided by the computer program that calculated leg circumference changes (LabVIEW 4.0, National Instruments, Austin TX). This program provided the negative pressure and time within that negative pressure that corresponded with 25, 50 and 75% $LBNP_{max}$. Using this information, the data points for HR, BPs, FBF, and ΔLC closest to the given

time were used in calculations. For values up to -40 mmHg, data for HR, BPs, and FBF was averaged for each of the 3 minute stages. Carotid sinus mechanoreflex sensitivities (ΔR-R) were also analyzed using a repeated measures ANOVA. If significance was found, a Scheffé post-hoc test was applied to identify where the differences existed. Subject characteristics, maximal LBNP tolerance, LBNP tolerance indexes (LTI), lean body mass, percent body fat and VO_{2max} were analyzed using independent t-tests. Correlations were calculated for fat free mass and LTI with CA-Cricket Graph III (Computer Associates International, Islandia NY). The significance level (alpha) was set at $P<0.05$ for all comparisons. Subject characteristics are reported as mean ± SD. All other data are reported as mean ± SE.

Chapter 4

Results

The data results reported pertain to the following hypotheses put forth in Chapter 1:

1) There will be a difference between maximal LBNP tolerance in individuals undertaking chronic resistance training and controls.

2) There will be a correlation between fat free mass and maximal LBNP tolerance.

The results are organized into the following sections: descriptive data, lower body negative pressure data, and neck chamber data.

Descriptive data

CRT subjects did not differ from CON in age ($p = 0.167$), height ($p = 0.050$, power = .52), percent body fat ($p = 0.593$), VO_{2max} ($p = 0.352$), or maximum heart rate ($p = 0.922$). There were significant differences between the CRT and CON subjects in body weight ($p = 0.003$), fat free mass ($p = 0.002$), years of resistance training ($p = 0.016$), 5-RM bench press ($p = 0.005$) and leg extension ($p = 0.002$), and resting leg and forearm circumferences ($p = 0.006$ and $p = 0.010$, respectively). See Table 3 for means ± SD.

Lower Body Negative Pressure Data

The CRT subjects had a significantly greater LBNP tolerance over the CON subjects, as noted by maximal negative pressure (-84.3 ± 6.1 (SE) mmHg vs. -60 ± 3.8 mmHg; $p = 0.005$; mean ± SE) and LTI (246.6 ± 17.0 mmHg•min vs. 175.1 ± 9.6 mmHg•min; mean ± SE; $p = 0.003$). See Figures 1 and 2.

Table 3: Physical characteristics of subjects (mean ± SD)

	CRT	CON
N	7	7
age (yrs)	26.7 ± 2.9	24.4 ± 2.9
weight (kg)	90.2 ± 8.3*	75.4 ± 6.5
height (cm)	179.5 ± 5.9	173.8 ± 3.6
body fat (%)	11.4 ± 3.0	12.9 ± 5.1
fat free mass (kg)	79.9 ± 9.1*	64.3 ± 5.89
VO_{2max} (ml/kg/min)	47.35 ± 3.93	44.80 ± 5.26
HR_{max} (beats/min)	187 ± 8	187 ± 8
yrs. of resistance training	5.9 ± 5.6*	0
5 RM bench press (kg)	101.6 ± 23.9*	64.9 ± 15.6
5 RM leg extension (kg)	106.9 ± 12.3*	77.7 ± 13.6
resting LC (cm)	39.5 ± 1.7*	34.9 ± 3.2
resting FC (cm)	32.4 ± 3.6*	28.0 ± 1.2

* significantly different from CON, $P < 0.05$
VO_{2max} = maximal oxygen uptake
HR = heart rate
5 RM = 5 repetition maximum
LC = maximal leg (calf) circumference
FC = forearm circumference

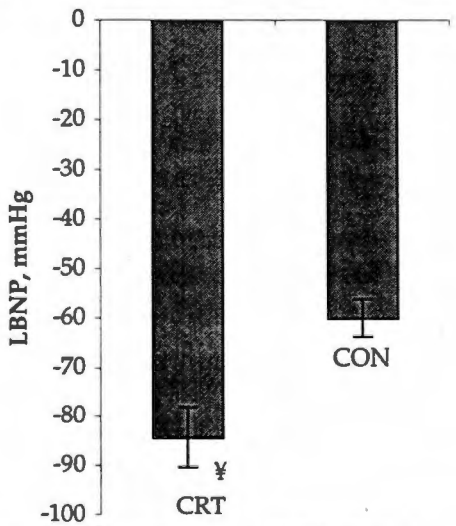


Figure 1: Maximal LBNP Tolerance for CRT and CON Subjects.
¥ Significantly different from CON, $p<0.05$. Data shown as mean ± SE. CRT = chronic resistance trained, CON = control.

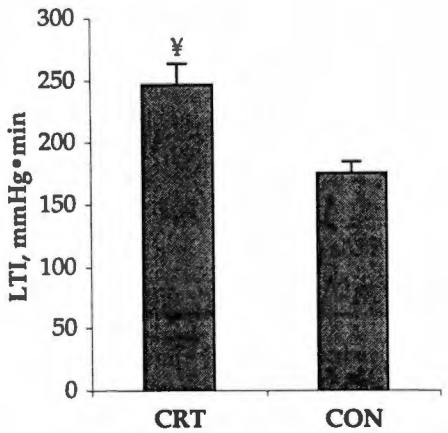


Figure 2: LTI for CRT and CON Subjects. ¥ Significantly different from CON, $p<0.05$. Data shown as mean ± SE. CRT = chronic resistance trained, CON = control

Figure 3 represents HR at absolute values of LBNP up to -40 mmHg and relative percentages (rest, 25%. 50%, 75% and 100%) of LBNP. At absolute levels of LBNP to -40 mmHg, there was a significant interaction between HR and group ($p = 0.0441$). At relative percentages of LBNP, a trend for HR x group interaction was noted ($p = 0.0604$). At absolute pressures beyond -20 mmHg and at 50% $LBNP_{max}$ and above, both groups showed a significant increase in HR over resting values ($p = 0.0001$ and 0.001, respectively).

Figure 4 shows that CRT and CON SBP was not different between groups up to -40 mmHg LBNP, and decreased from baseline to -40 mmHg, becoming significantly different from baseline at -30 mmHg ($p = 0.0001$). At relative levels of LBNP, there was a trend for lower SBP in the CRT group ($p = 0.0629$). The decrease in SBP became significantly different from resting for both groups at 75% and 100% of $LBNP_{max}$ ($p = 0.001$).

Figure 5 represents DBP at absolute and relative levels of LBNP. There was no significant difference between CRT and CON groups at either absolute pressure values up to -40 mmHg ($p = 0.1830$) or relative levels ($p = 0.1975$) of LBNP, nor from baseline to either -40 mmHg ($p = 0.1455$) or $LBNP_{max}$ ($p = 0.7713$).

Figure 6 shows that MABP was not different between CRT and CON at any negative pressure up to -40 mmHg ($p = 0.1944$) or percentage of $LBNP_{max}$ ($p = 0.0722$). However, both groups had a decrease in MABP at 100% $LBNP_{max}$ vs. baseline ($p = 0.0031$).

Figure 7 represents the leg circumferences (LC) of the groups at absolute and relative percentages of $LBNP_{max}$. Leg circumference was significantly greater in the CRT group throughout LBNP ($p = 0.0069$ for absolute values to -40 mmHg and $p = 0.0054$ for relative values). Both groups had leg

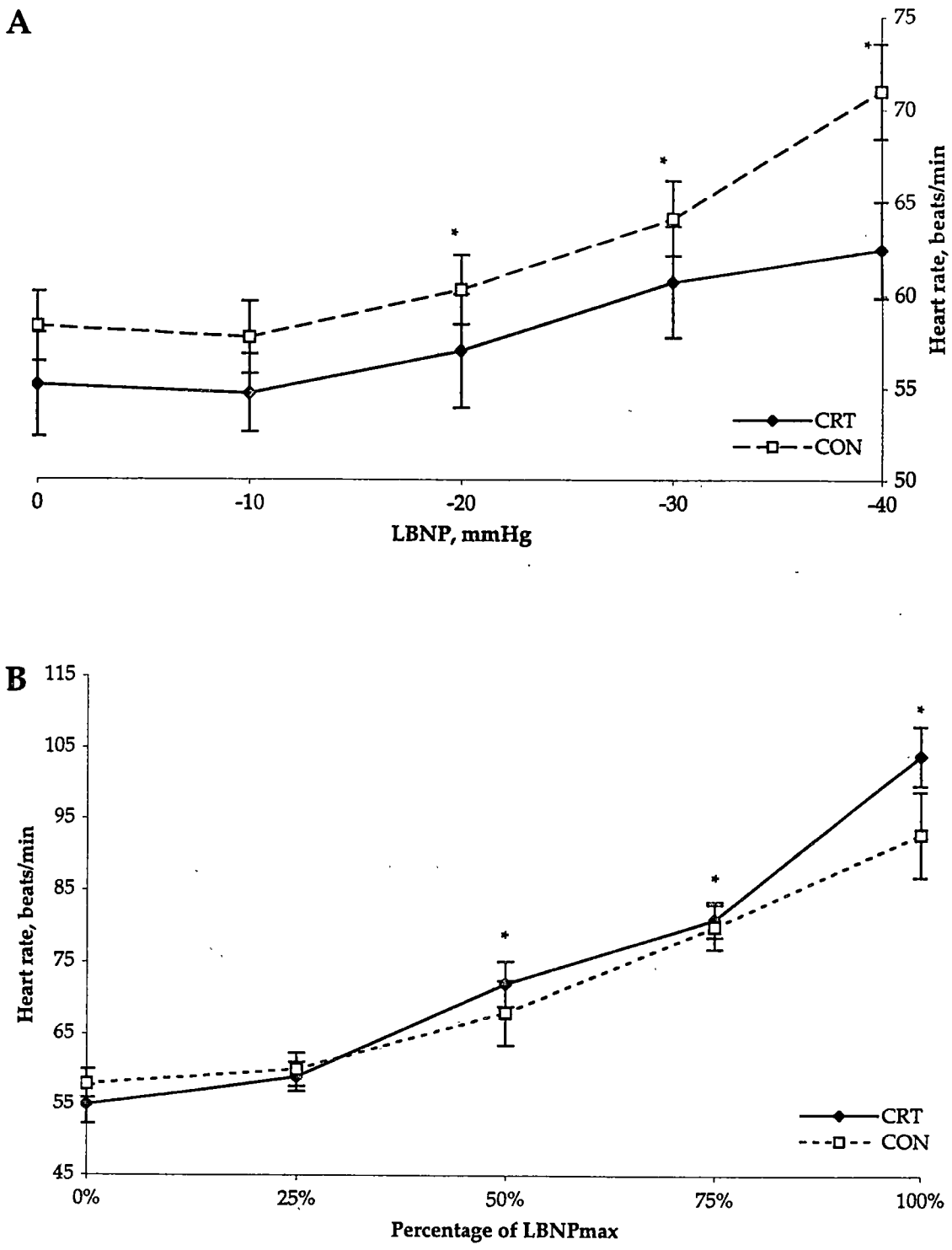


Figure 3: Heart Rate at Absolute and Relative Percentages of LBNP.
A: Absolute values of LBNP. * Significantly different from 0 mmHg (rest), $p<0.05$.
B: Relative percentages of $LBNP_{max}$. * Significantly different from 0% of $LBNP_{max}$ (rest), $p<0.05$. Data shown as mean ± SE. CRT = chronic resistance trained, CON = control

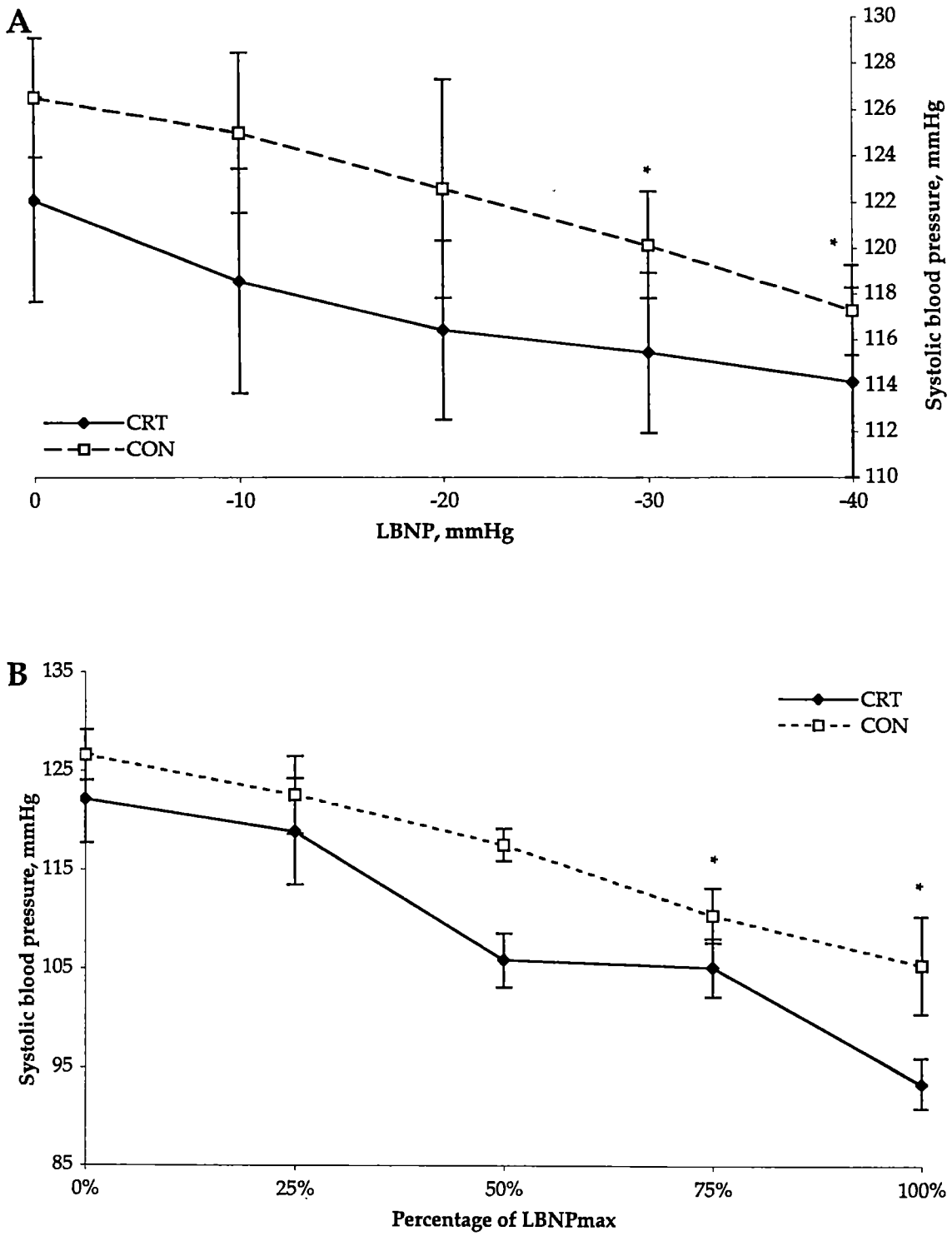


Figure 4: Systolic Blood Pressure at Absolute and Relative Percentages of LBNP. A: Absolute values of LBNP. * Significantly different from 0 mmHg (rest), $p<0.05$. B: Relative percentages of $LBNP_{max}$. * Significantly different from 0% $LBNP_{max}$ (rest), $p<0.05$. Data shown as mean ± SE. CRT = chronic resistance trained, CON = control

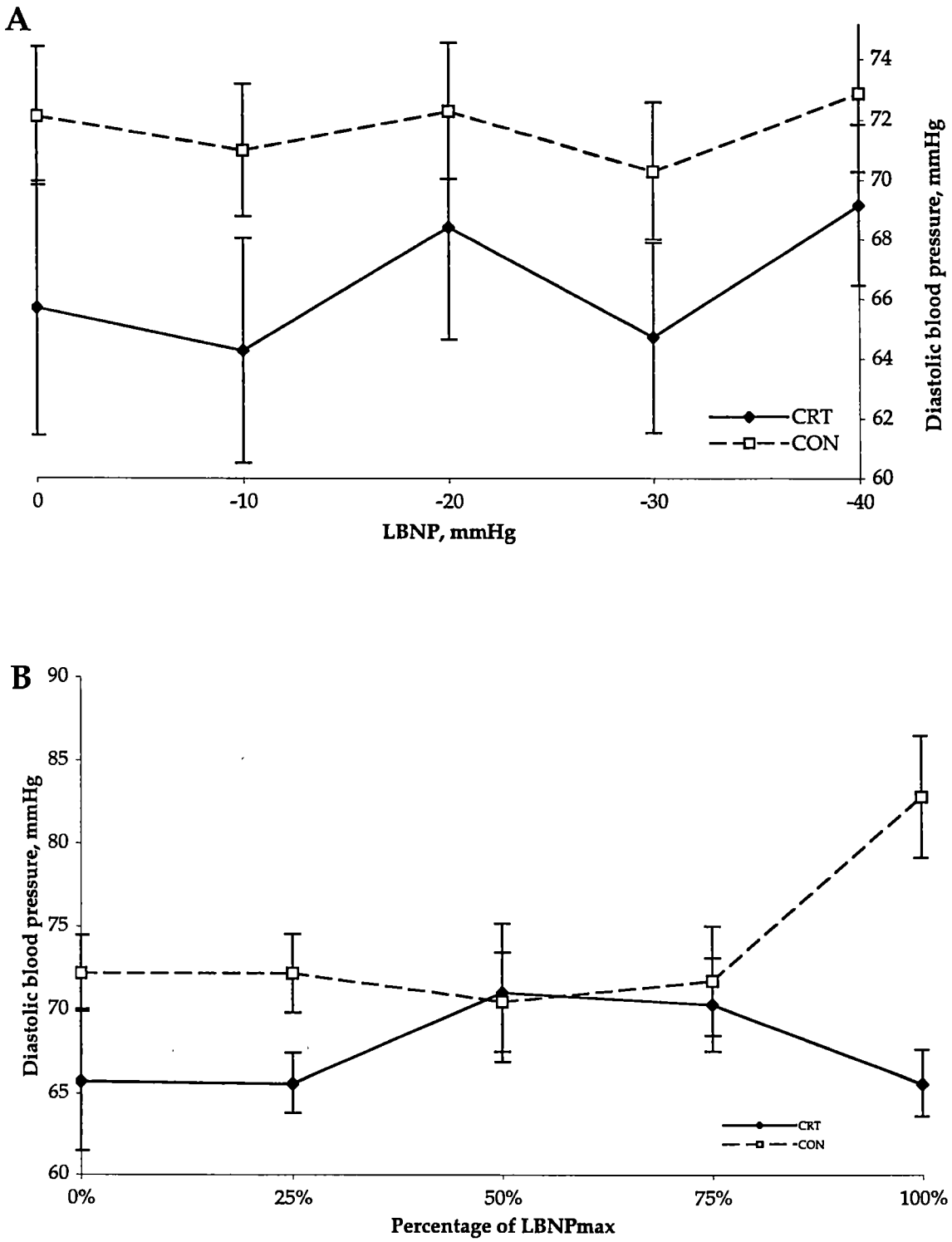


Figure 5: Diastolic Blood Pressure at Absolute and Relative Percentages of LBNP. A: Absolute values of LBNP. B: Relative percentages of $LBNP_{max}$. No significant differences by group or by pressure or percentage LBNP at $p<0.05$. Data shown as mean ± SE. CRT = chronic resistance trained, CON = control

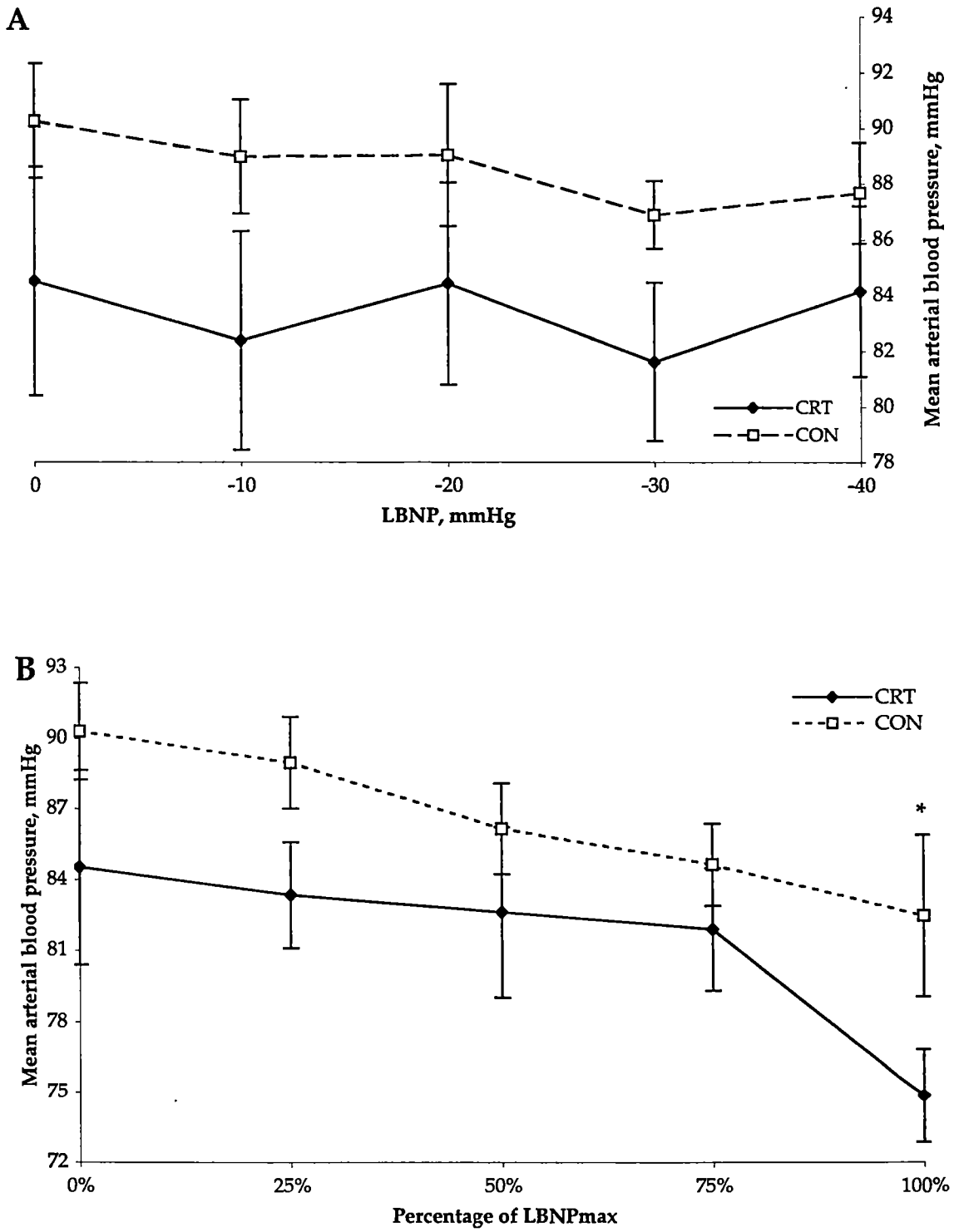


Figure 6: Mean Arterial Blood Pressure at Absolute and Relative Percentages of LBNP. **A**: Absolute values of LBNP. No significant differences by group or LBNP pressure. **B**: Relative percentages of $LBNP_{max}$. * Significantly different from 0% $LBNP_{max}$ (rest), $p<0.05$. Data shown as mean ± SE. CRT = chronic resistance trained, CON = control

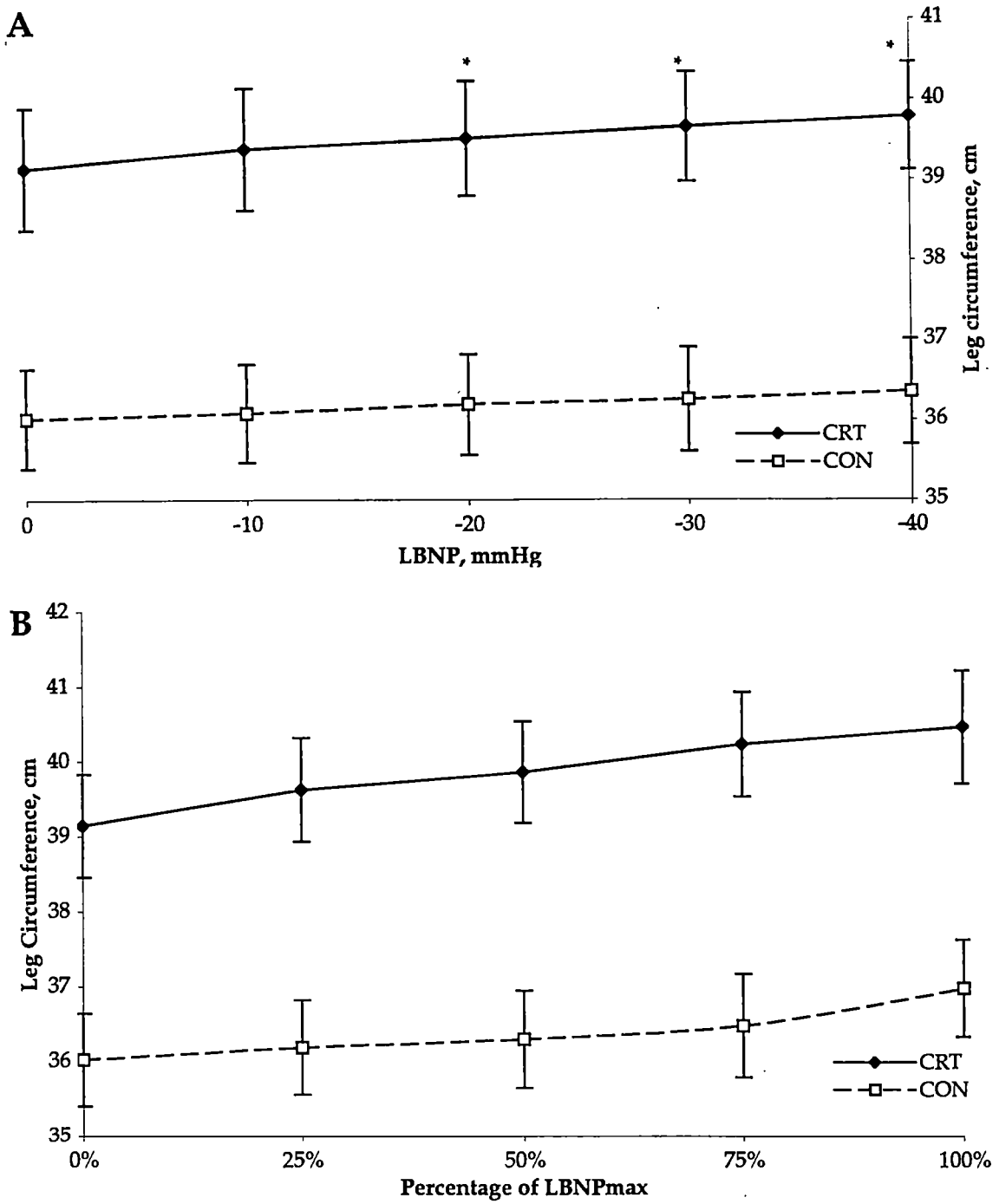


Figure 7: Leg Circumferences at Absolute and Relative Percentages of LBNP
A: Absolute values of LBNP. CRT and CON were significant different at all pressures, $p<0.05$. * Both groups significantly different from 0 mmHg (rest), $p<0.05$. B: Relative percentages of $LBNP_{max}$. CRT and CON are significantly different at all percentages of $LBNP_{max}$. * Significantly different from 0% $LBNP_{max}$ (rest), $p<0.05$. Data shown as mean ± SE. CRT = chronic resistance trained, CON = control

circumferences significantly different from rest at -20 mmHg through -40 mmHg ($p = 0.0001$) and starting at 25% of maximal LBNP ($p = 0.001$). There was no significant interaction in either absolute ($p = 0.1999$) or relative ($p = 0.2550$) terms, indicating both groups had leg circumferences increase in parallel.

Figure 8 represents forearm blood flow (FBF) at absolute and relative levels of LBNP. From -20 mmHg through -40 mmHg of LBNP, there was a significant decrease in FBF from resting values ($p = 0.0029$), with no difference found between groups at absolute values up to -40 mmHg ($p = 0.2220$). At relative values of $LBNP_{max}$, there was no significant difference between groups ($p = 0.0651$), although there was a trend for a difference between relative percentages of $LBNP_{max}$ ($p = 0.0556$).

Figure 9 depicts forearm vascular resistance (FVR) at absolute and relative values of LBNP. The groups were not significantly different at either absolute ($p = 0.1309$) or relative values ($p = 0.1613$), nor was there a difference between the percentages of $LBNP_{max}$ used in this study ($p = 0.0532$), although a trend was suggested. In absolute terms, at -40 mmHg of LBNP, both groups had FBF values significantly greater than resting values ($p = 0.0260$).

A simple regression between LTI and fat free mass (FFM) indicated a trend ($p = 0.0785$; Figure 10), as does a regression between LTI and forearm circumference ($p = 0.0527$; Figure 11). Leg circumference was significantly correlated with LTI ($p = 0.0183$; Figure 12), as was 5-RM leg extension ($p = 0.0076$; Figure 13). Multiple regression analyses indicated that using FFM and 5-RM leg extension to predict LTI was significant ($p = 0.0113$), as was using FFM and LC for prediction of LTI ($p = 0.0112$). Beta (slope) for the multiple regression using FFM and 5-RM leg extension was -0.016; for FFM and LC,

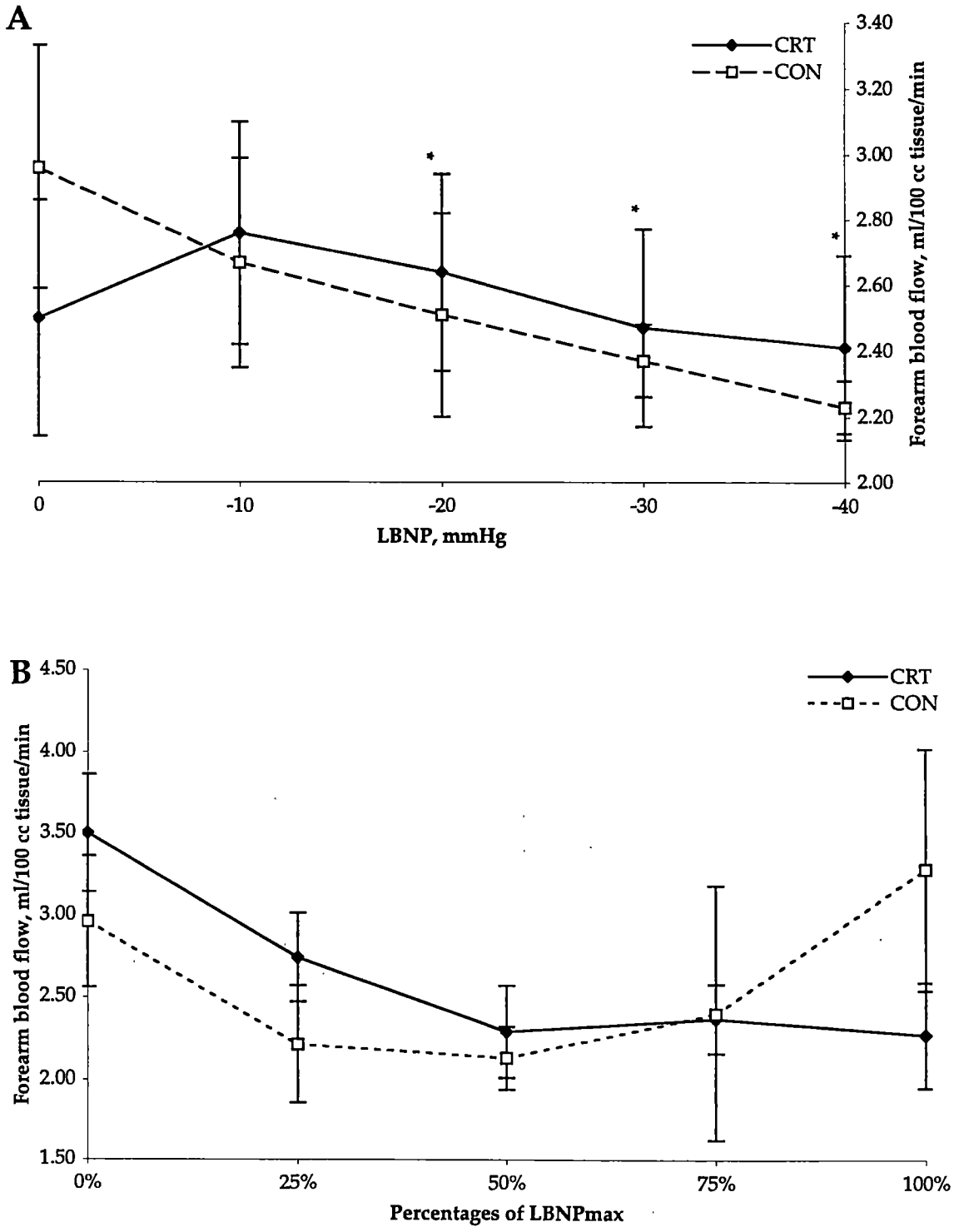


Figure 8: Forearm Blood Flow at Absolute and Relative Percentages of LBNP
A: Absolute values of LBNP. * Significantly different from 0 mmHg (rest), $p<0.05$. **B**: Relative percentages of $LBNP_{max}$. No significant differences by group or percentage of $LBNP_{max}$ at $p<0.05$. Data shown as mean ± SE. CRT = chronic resistance trained, CON = control

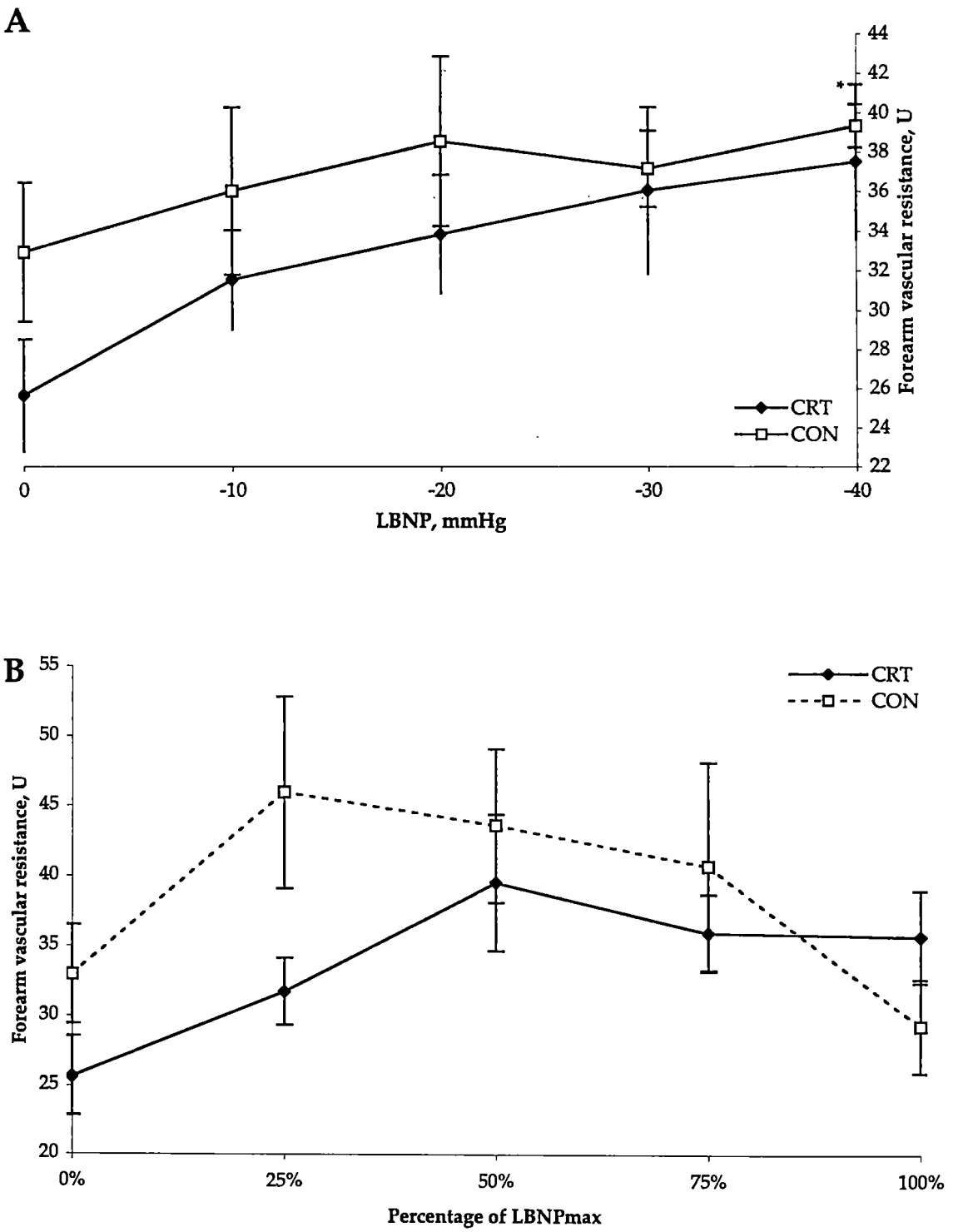


Figure 9: Forearm Vascular Resistance at Absolute and Relative Percentages of LBNP. A: Absolute values of LBNP. * Significantly different from 0 mmHg (rest), $p<0.05$. B: Relative percentages of $LBNP_{max}$. No significantly differences by group or percentages of $LBNP_{max}$ at $p<0.05$. Data shown as mean ± SE. CRT = chronic resistance trained, CON = control

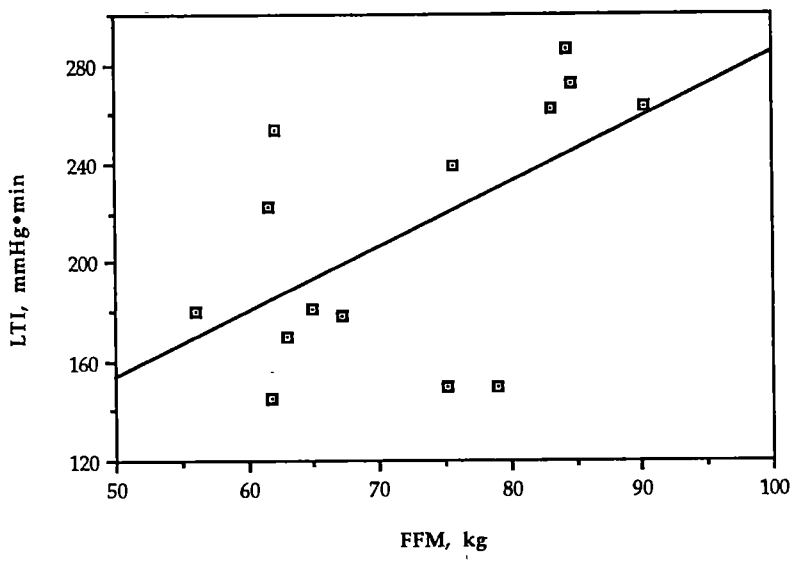


Figure 10: Correlation Between Fat Free Mass and LTI.
$y = 39.718 + 2.3405x$ $r = 0.505$ $r^2 = 0.255$

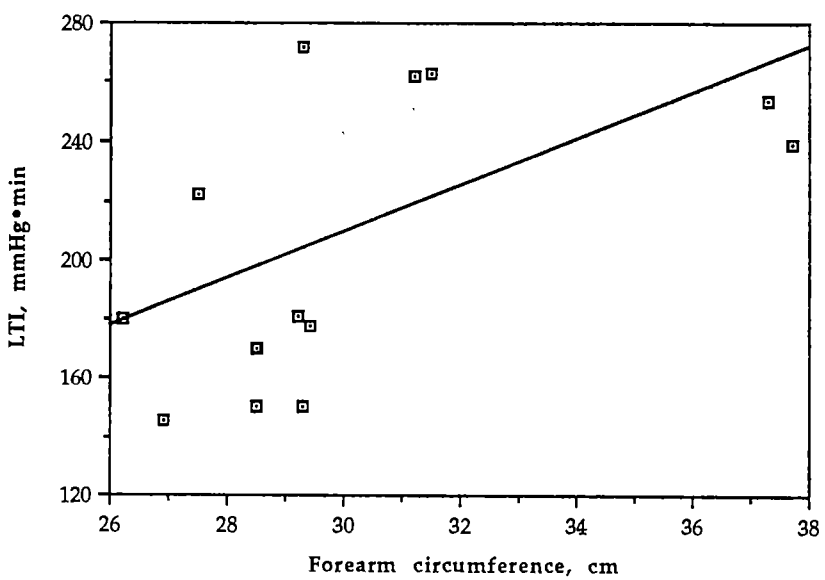


Figure 11: Correlation Between Forearm Circumference and LTI.
$y = -26.319 + 7.8498x$ $r = 0.527$ $r^2 = 0.278$

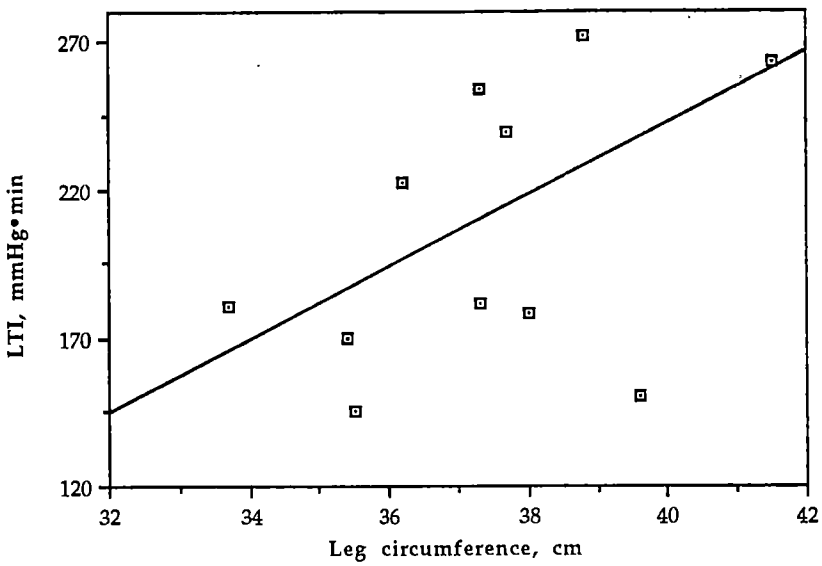


Figure 12: Correlation Between Leg Circumference and LTI.
$y = -244.57 + 12.510x$ $r = 0.525$ $r^2 = 0.276$

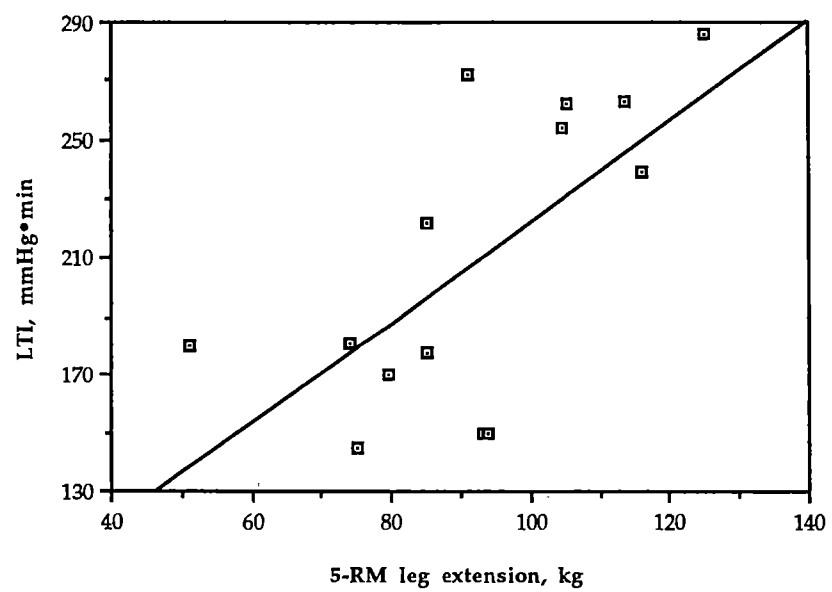


Figure 13: Correlation Between 5-RM Leg Extension and LTI.
$y = 47.831 + 1.7663x$ $r = 0.679$ $r^2 = 0.461$

beta was -0.110. A Type I error would likely be made if the regressions were accepted as significant. A multiple regression using 3 variables (FFM, 5 RM leg extension, LC) did not improve the model ($p = 0.0133$). A multiple regression using LC and 5 RM leg extension to predict LTI was non-significant ($p = 0.3384$).

Neck Chamber Data

Figure 14 depicts the ΔR-R interval/carotid sinus pressure relationships for the CRT and CON subjects. A repeated-measures ANOVA indicated no between-group differences in ΔR-R ($p = 0.7414$). Finding slope values for both lines is currently beyond the limits of this researcher's knowledge and understanding. However, regression lines for both groups are as follow:

CRT: $y = -0.0007x^3 + 0.2956x^2 - 34.916x + 1164.6$ $R = 0.9958$

CON: $y = -0.0002x^3 + 0.0799x^2 - 9.2243x + 220.74$ $R = 0.9974$

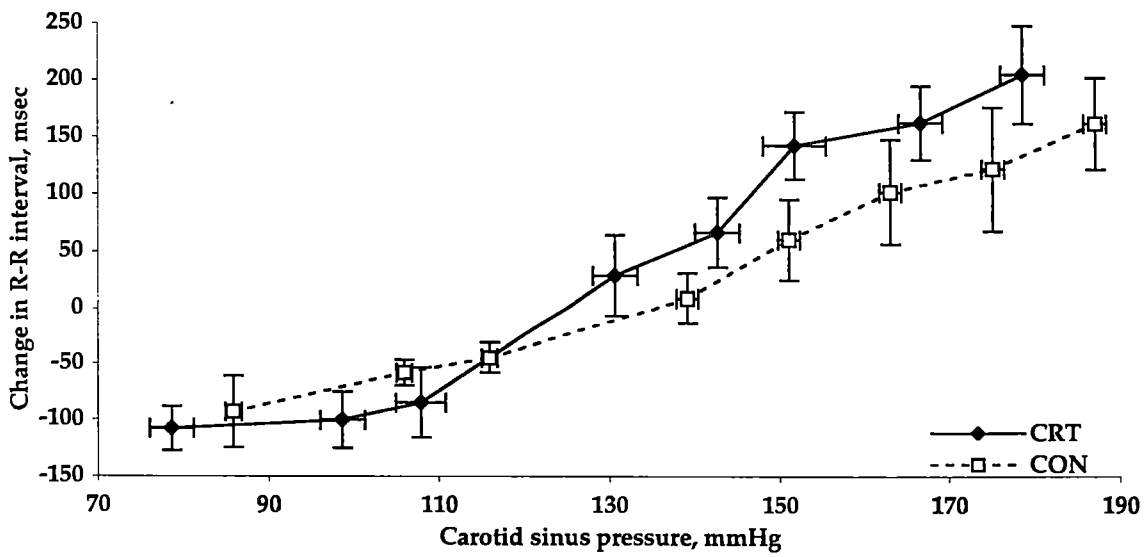


Figure 14: Carotid Sinus Pressure vs. Change in R-R Interval
Data shown as mean ± SE. CRT = chronic resistance trained, CON = control

Chapter 5

Discussion

Effects of Chronic Resistance Training on LBNP Tolerance

This study found that individuals who perform resistance training do have an increased LBNP tolerance over non-resistance trained individuals as evidenced by the ability to tolerate higher levels of LBNP. This is in agreement with previous studies (32, 64, 82, 88, 91). Lightfoot et al. (64) performed is the only other study to have taken CRT subjects to maximal LBNP tolerance. Their CRT subjects had a mean LBNP tolerance slightly over -90 mmHg. We did not find LBNP tolerance to be quite as high in the CRT subjects, having a mean LBNP tolerance of -84.28 mmHg. This is between the mean values found by Lightfoot et al. (64) in their 12-week resistance trained individuals and the CRT subjects who had been involved in resistance training for a minimum of 4 years. One of our CRT subjects was found to have a $LBNP_{max}$ of -50 mmHg; he had not resistance trained for the week prior to testing (Spring Break), and had been active in cardiovascular fitness activities during that time. It is unknown whether or not this contributed to his low LBNP tolerance, or if some other unidentified factor was involved. If his LBNP tolerance is removed from the data set, the mean $LBNP_{max}$ for the remaining subjects becomes -90 mmHg. This would agree more closely with the results found by Lightfoot et al. (64).

Venous Compliance

The CRT group had a significantly larger resting leg circumference, and, though statistically non-significant, were able to tolerate more venous

pooling (max %ΔLC = 3.38 ± 0.68 vs. 2.68 ± 0.82, p = 0.1558). This concurs with previous studies that have indicated there is little difference in circumference increases (venous pooling) between groups at given submaximal LBNP pressures (50, 62, 64, 90), although Smith and Raven (88) found their untrained control subjects to have significantly less change in leg circumference than their endurance-trained (88)subjects. Our study indicated that the CRT and CON subjects had calf circumferences increase at the same rate up to -40 mmHg, as indicated by significant differences between groups and at the different levels of LBNP. This may indicate an increased tolerance of venous pooling, when taken out to higher levels of LBNP. Figure 15 shows the percent change in leg circumferences in all subjects, CRT and CON, through maximal LBNP tolerance. There appears to be little difference between LC changes in either relative or absolute terms, as noted in Chapter 4 and Figure 7. Individuals who perform chronic resistance training appear to

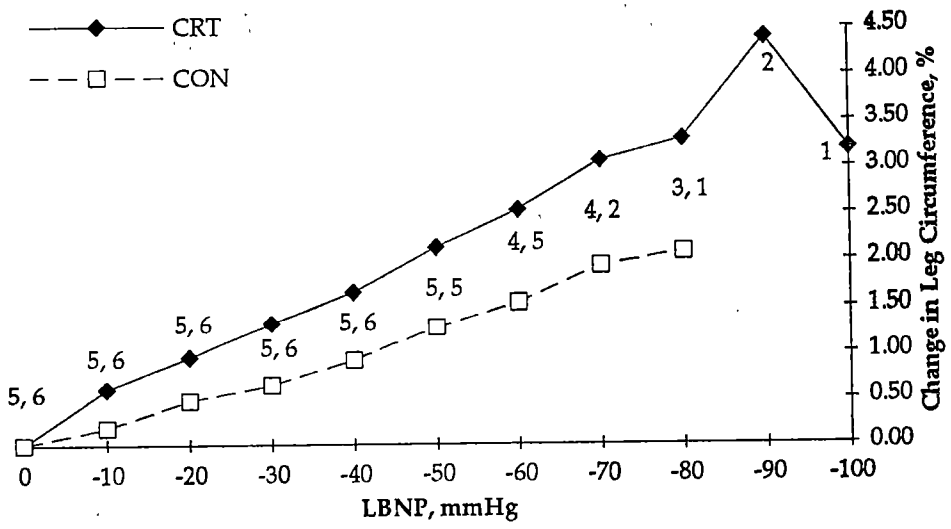


Figure 15: Percent Change in Leg Circumference From Rest Through Maximal LBNP. Numbers indicate total subjects (n) for CRT and CON, respectively, at each level of LBNP. Data represented as means. CRT = chronic resistance trained, CON = controls

be able to stand greater percent changes in calf circumference during LBNP exposure.

Cardiopulmonary Mechanoreceptor Sensitivity

The observed blood pressures responses during the maximal LBNP tests were as expected and concur with past research (62, 64, 66, 90). Both SBP and HR decreased significantly with increasing negative pressure, with no difference in DBP or MABP. Whereas Lightfoot et al. (64) noted an increase in MABP in their CRT subjects, we did not. The magnitude of the fall in MABP was the same as that seen in our controls.

HR, FBF and FVR decreased as LBNP increased and were not significantly different between the CRT and CON at any level or percentage of LBNP. This was expected, and concurs with previous studies (26, 50, 62, 64, 66, 74, 82, 90). With all of these variables, however, the CRT took longer to reach the same values seen in the CON. By looking at the changes and responses at given percentages of $LBNP_{max}$, it can be seen that both groups respond similarly; the CRT, however, appear to be able to regulate BPs, HR and FBF better, which resulted in a longer exposure to LBNP before pre-syncopal signs appeared.

Arterial Mechanoreceptor Sensitivity

We found no significant difference between the ΔR-R for the CRT and CON. Lightfoot et al. (64) noted a slightly flattened slope for their CRT subjects, whereas our findings did not (Figure 13). Research regarding the effect of training on maximal ΔR-R slope has been equivocal; some have noted significant differences in slope following endurance and resistance

training as compared to untrained (9, 75, 90), while others have not (35, 62, 64). Unfortunately, the slopes for the arterial mechanoreflex curves found in this present study are currently not available for comment.

Detraining appears to occur rapidly following cessation of physical activity or bedrest (25, 38). Eckberg and Fritsch (30) noted a decrease in maximum slope after 10 days of head-down tilt ($p = 0.11$), however, it does not appear to be significantly different until some time beyond 10 days. Following 30 days of not exercising, Convertino et al. (22) had a highly significant alteration in maximum carotid sinus mechanoreceptor slope ($p = 0.00008$). If a person were to stop either endurance or resistance training, there would be a decrease in arterial mechanoreceptor sensitivity (22, 25, 30, 38).

Skeletal Muscle

The effect of FFM on LBNP tolerance was noted as a trend, as well as when used in a multiple regression with 5-RM leg extension or LC. This is in contrast to Lawler et al. (58), who found that leg muscle mass did not correlate with LBNP tolerance. However, they did not have a statistical difference in the leg masses between the high- and low-leg lean mass groups. If the *N* for the present study had been greater, thus increasing our power to detect a difference, there may have been a stronger correlation between FFM and LBNP tolerance.

Suprisingly, 5-RM leg extension correlated strongly with LBNP tolerance index (LTI). Balldin et al. (8) noted a significant correlation ($r = 0.67$, $p<0.05$) between static knee extensor endurance and centrifuge tolerance. While we were testing dynamic strength instead of isometric endurance, our

findings agree that quadriceps strength and/or endurance is important to orthostatic tolerance.

The multiple regressions indicated that while FFM by itself was not a significant factor in predicting LTI, it was vital to include it in the regression. FFM, in combination with the 5-RM leg extension score or with LC, proved to be statistically significant. However, since the slope (beta) was small (-0.002), we could not accept the regression as being significant. If more subjects were added to the model, beta might improve, and we might be able to accept the model. Increasing the total number of subjects to 20-24 and maintaining an equal number in each group would greatly increase the power of the statistics.

It appears that the type of resistance training program undertaken is not important to LBNP tolerance. Subjects in this study varied in resistance training protocols, ranging from body-weight only exercises, i.e. pull ups, push ups, and squats, to endurance protocols, i.e. high repetitions with low weight, to traditional full-body bodybuilder training. It appears that training protocol is not important to improving tolerance, as long as the training occurs against resistance. This may be important to individuals that do not relish the thought of entering a weight room or do not want to increase muscle size but would like to increase there tolerance of venous pooling.

Conclusions

In terms of the hypotheses stated in Chapter 1, we can accept the hypothesis that chronic resistance training does increase maximal LBNP tolerance; a significant difference was found between individuals that had chronically resistance trained and those that had not. Our second hypothesis, that there would be a correlation between lean body mass and the LBNP

tolerance index, cannot be accepted at this point. A larger number of subjects was needed in this study to provide increased levels of power.

Suggestions for Further Research

Lawler et al. (58) used both male and female subjects. Our present study utilized only males. A future project might look specifically at females that resistance train, and see if there is a different regression line for their small lean body mass in comparison to the males. Also, considering the smaller stature and mass of females it would be interesting to note if they would be able to tolerate a similar maximal LBNP as the male counterparts.

Also, the quadriceps and abdominals are both postural muscles and have been correlated with LTI, singularly and in conjunction with other muscle groups. Testing other postural muscles for strength and/or endurance may find another correlation.

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Appendixes

Appendix A

Informed Consent Document

UNCCHARLOTTE
The University of North Carolina at Charlotte
9201 University City Boulevard
Charlotte, N.C. 28223-0001

Health Promotion
and Kinesiology
704/547-4695
FAX 704/547-3350

Orthostatic tolerance in males who perform chronic resistance training versus controls
Informed Consent

Investigators: Tim Lightfoot, Sharon Boon

When astronauts return from space on the Space Shuttle, some experience lightheadedness or fainting when they try to stand up soon after landing. Technically, this is called orthostatic intolerance and is related to an inability to maintain blood pressure. The lightheadedness is due (in part) to blood pooling in the legs, and researchers are trying to determine ways to reduce this effect of space travel. A previous study in this lab suggested that resistance training can actually improve an individual's tolerance to simulated venous pooling. However, limited data is available regarding whether tolerance continues to increase with continued resistance training. You are invited to participate in a research project to see if regular participation in weight training helps to prevent lightheadedness when an individual is challenged with a procedure that causes blood to pool in the legs.

METHODS, BENEFITS AND RISKS OF PARTICIPATION

You will be asked to attend 3 sessions. Before you come in for any session, please do not exercise or drink alcohol for 24 hours prior to testing, do not have caffeine the day of testing, and do not eat or drink anything but water for 4 hours prior to testing.

If you exhibit any dysrhythmia (heart rhythm disturbances) during any of the testing, you will be immediately removed from the study.

Session 1: Informed Consent, Health and Medical History, VO_2max test, and LBNP Orientation test [2-hour session]

Protocol: During this session, you will be asked to read and sign the informed consent document and complete a medical history questionnaire. If you do not indicate any health problems that might adversely be affected by testing, you will be asked to perform a running test for measurement of maximal oxygen uptake; ECG will be monitored during this test. Following this test, you will be placed in the LBNP chamber for an orientation test, with your lower body sealed inside the chamber. After a baseline period, negative pressure will be initiated at a rate of -10 mmHg every 3 minutes, until presyncopal signs occur or subjective symptoms indicate the need to terminate the test. ECG, blood pressure, forearm blood flow and subjective symptoms will be monitored during this test.

Procedure: Your height and weight will be measured and you will be asked to perform an aerobic power (running) test on a treadmill.

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Ten electrodes will be attached to your chest to measure heart rate during the test, and you will do a walk/jog "warm-up" prior to the actual test. The speed will be increased gradually until a heart rate of 150 beats per minute is measured. Following a brief rest period, you will be asked to run at this speed while wearing a nose clip/respiratory value assembly that collects your expired air so we can measure your energy expenditure. The speed will remain the same throughout the test, but the grade (elevation) will be increased 1% per minute until you reach volitional exhaustion (you cannot continue running). This is a point that only you can determine. Two minutes following your maximal effort, we will prick one of your fingers (this may hurt slightly) and take a small sample of blood (about 2 drops) to measure the amount of lactic acid in your system. The running may cause some muscle soreness to occur, but this should not last more than 48 hours. This type of maximal test may also cause a disorder of the heart beat and/or a heart attack, though it is very unlikely for someone your age and health status. The information you gain from doing this fitness test will help you in planning modifications to your fitness program.

Following the treadmill test, you will be asked to complete an orientation session in the lower-body-negative-pressure (LBNP) chamber. You will lie down in this clear plexiglass chamber and a rubber "skirt" will seal the chamber around your waist. After you have been lying comfortably in the chamber, 3 electrodes will be attached to your left leg to measure electrical activity in your leg. A cuff to measure blood pressure will be placed around your left arm, and 2 small measurement devices, called strain gauges, will be placed on your right upper arm and right leg. These strain gauges will help us monitor how much fluid is shifting in your body during the test. To help us with the measurements in your arm, we will also place a small cuff around your wrist. The upper cuff will be inflated every 30 seconds for about 8 seconds, followed by a release of the pressure. The wrist cuff will be inflated slightly throughout the whole experiment. Resting data will be collected for 3 minutes and then the pressure in the LBNP chamber will be reduced every 3 minutes.

The only thing that most people feel during this test is air moving around their waist. During this LBNP test there may be some slight discomfort during the measurements in the right arm, which may cause your hand to "fall asleep." Just before we stop the LBNP test you may feel nauseous, sweaty, clammy, or you may not experience anything. These feelings are highly variable and different people feel different symptoms. These symptoms will go away immediately when we stop the test.

There is a possibility that you could faint during the LBNP test. However, the guidelines we use to stop the LBNP test make it unlikely that you will faint during this procedure. In about 1500 tests in the past 10 years, we have had only 1 subject faint. The subject recovered within 15 seconds.

Session 2: Neck Chamber test, LBNP test, Orientation to Strength Testing (bench press and leg extension) [2-hour session, at least 2 days after Session 1]

Protocol: This session will begin with you undergoing a neck chamber test, which involves applying pressure (positive and negative) to the carotid arteries to "fool" the body into thinking it has had a change in blood pressure (decrease or increase, respectively), and observing the heart rate response. After the neck chamber, ECG and blood pressure cuff have been applied, suction or pressure will be applied to your neck. Following this test, you will again undergo a LBNP chamber test, following the same protocol as above. When this is completed, you will be shown the exercises to be used for strength testing (bench press and leg extension), and then will be asked to perform 4 sets of the exercises so that you may become comfortable with the movements.

Procedure: During the second visit, you will have a neck chamber test and another LBNP test, followed by an orientation to the strength testing (bench press and leg extension). Before you

come in for this session, please remember to not exercise or drink alcohol for 24 hours prior to testing, do not have caffeine the day of testing, and do not eat or drink anything but water for 4 hours prior to testing.

For the neck chamber test, we will use a 12-lead ECG and a blood pressure cuff to monitor your heart rate and blood pressure responses. You will rest for about 20 minutes during which time a small chamber will be placed around your neck (your face will be in the open) to allow suction or pressure to be applied to your neck. You will be asked to inhale and hold your breath for 5 seconds while baseline heart rate is measured and then pressure is applied. Each pressure is applied 5 times, for a total of 8 pressures. If you have a profound drop in blood pressure or adverse reaction during neck chamber testing, testing will be stopped. When suction/pressure is applied we can record your heart rate responses to the suction/pressure.

After the neck chamber test, you will do another LBNP test. You will again have all the instrumentation attached, as mentioned above. This test will be performed in the same manner as your orientation test.

Following the neck and LBNP chamber tests and a short recovery period, we will give you an orientation session to the strength testing exercises. If you have not weight trained before, this will help you learn the movements prior to actually doing the tests. We will demonstrate and then have you perform 2 different exercises: the bench press and the leg extension. You will do warm-up and stretching exercises prior to performing the movements to reduce the risk of injury and to decrease potential soreness. During the lifts, you will have 2 people ready to assist you during the repetitions if you are unable to maintain balance or complete the repetition, to enforce correct lifting technique, and to provide assistance as needed. These 'spotters' are there to minimize risk of injury. Between tests, you will be given a 3 minute rest. We will ask you to lift as much weight as possible, in good form and without assistance, 5 times. If you can do more than 5 repetitions, weight will be added. We will attempt to reach your maximum weight in 3 to 6 attempts. This is called a repetition maximum (RM) test. You may experience some muscle soreness, but this should not last more than 48 hours. This type of maximal test may also cause a temporary elevation in blood pressure and there is a slight risk of damage or injury to the muscles and joints being used.

Even though we have a great deal of experience with these techniques, there is a possibility that this study may involve risks that we cannot predict. In the event that you are hurt as a result of this research project, UNC Charlotte has no emergency medical facilities on campus but will promptly contact the Emergency Medical Services of Mecklenberg County. Your medical treatment, as well as other medical expenses, will be paid by you or your health insurance in your usual manner. No compensation or reimbursement is available from UNC Charlotte or the investigators in this study.

Session 3: Hydrostatic weighing and strength testing [1.5-hour session, at least 2 days after Session 2]

Protocol: When you enter the lab, you will be weighed then have your residual volume measured by helium dilution method. Following this, you will enter the hydrostatic weighing tank. You will be asked to exhale completely and submerge several times to determine an underwater weight. Testing for muscle strength will follow the completion of the underwater weighing. For the strength tests, you will perform the bench press with as much weight as possible for a maximum of 5 repetitions. The leg extension exercise will be tested in a similar fashion.

Procedure: At least 2 days after your second visit, you will be asked to return to Belk Gym for your third and final session. This session will consist of underwater weighing to measure body fatness, and maximal strength testing. Before you come in for this session, please

remember to not exercise or drink alcohol for 24 hours prior to testing, do not have caffeine the day of testing, and do not eat or drink anything but water for 4 hours prior to testing.

Before doing the underwater weighing test, you will breathe into a machine to measure your lung volume. After this, we will ask you to get in the underwater weighing tank. You will sit on a suspended chair and, when you are ready, you will exhale all your air and submerge yourself. We will ask you to this several times for accuracy. If you are not accustomed to being in the water, this may be a little awkward. We will not rush you; you will proceed at a rate at which you feel comfortable.

Following the underwater weighing, we will take you downstairs to the weight room and have you perform 5-RM tests on the bench press and leg extension, following the same procedure as described in Session 2.

The information you gain from doing this fitness test will help you in planning modifications to your fitness program. Aside from this, you will receive no direct benefits. However, the results of this study will help further the current understand the effects of training on orthostatic tolerance.

CONFIDENTIALITY
Only the investigators listed at the top of this informed consent will have access to the any records pertaining to this study. These records will remain locked in a file cabinet in the Functional Health Laboratory (240 Belk Gymnasium). Ms. Boon will retain a copy of data with participants identifiable only by subject number when she returns to the University of Tennessee, Knoxville. When data is compiled and reports written, the identity of all subjects will remain confidential.

RIGHT TO ASK QUESTIONS/RIGHT TO WITHDRAW FROM THIS STUDY
If you sign this form, you are willing to join the research project described above. You should ask the investigators listed above any questions you may have about this research study. You may ask questions in the future if you do not understand something that is being done.

The records from this research study will be kept confidential and will not be given to anyone who is not helping on this study, unless you agree to have the records released.

If you have any other questions about the study, you should call Dr. Tim Lightfoot or Sharon Boon at (704) 547-4692. UNC Charlotte is eager to ensure that all research participants are treated in a fair and respectful manner. If you want to talk to about this research because you think you have not been treated fairly, or you think you have been hurt by joining the study, or if you have any other concerns or questions about your treatment as a subject in this project, contact Dr. Linda Moore, Department of Adult Health Nursing, Charlotte, NC 28823, (704)547-4669.

You are a volunteer. As such you have the right to withdraw from this study at any time and will not be penalized in any way if you decide to withdraw. Your satisfactory completion of any course or other educational opportunity at the University of North Carolina - Charlotte is not based on your participation in this study.

CONSENT
By signing below, I am indicating that I am at least 18 years of age, and have read the above information and consent to my participation in this study. I have had the procedures and potential risks explained to me and have had all my questions answered to my satisfaction. I understand that I will receive a copy of this consent form for my records.

Participant's Signature: _____ **date**_____

Investigator's Signature: _____ **date**_____

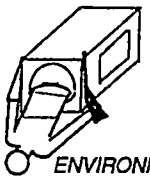
Appendix B

Exercise and Medical History Form



EXERCISE

UNC-Charlotte
FUNCTIONAL HEALTH LABORATORY
MEDICAL HISTORY



ENVIRONMENTAL EXTREMES

Instructions

Please complete each question as accurately as possible. All information provided is confidential.

Information About the Individual

1. Name - _____ 2. Age - _____

3. Date of Birth - _____ 4. Mailing Address _____

_____

5. Gender - _____ 6. Ethnic background: _____

7. Home Phone - _____ 8. Work Phone - _____

9. Person to contact in emergency - _____ 10. Phone - _____

Medical History

11. Do you currently have any medical complaints? Yes No
(If Yes, please specify)

---

12. Are you on any prescribed or over-the-counter medication? Yes No
(If Yes, please specify)

---

13. Cardiorespiratory History (circle either Yes or No)

Do you presently have heart disease?	Yes	No
Have you ever had heart disease?	Yes	No
Do you have a family history of heart disease?	Yes	No
Do you have a heart murmur?	Yes	No
Do you have occasional chest pains?	Yes	No
Have you ever fainted?	Yes	No
Do you suffer from unexplained, repeated fainting?	Yes	No
Do you have high blood pressure?	Yes	No
Do you have asthma or allergies?	Yes	No
Do you have any pulmonary (lung) problems?	Yes	No
Do you have any peripheral vascular disease problems (Raynaud's)?	Yes	No

Explain any Yes response _____

---

14. Musculo-skeletal History

Do you have any muscle injuries now?	Yes	No
Have you had any muscle injuries in the past?	Yes	No
Do you have any bone or joint injuries now?	Yes	No
Have you had any bone or joint injuries in the past?	Yes	No
Have you ever had swollen joints?	Yes	No

Explain any Yes response _____

_____

15. General History

Have you had or do you have:

Adrenal Disease	Yes	No
Hypoglycemia	Yes	No
Seizures	Yes	No
Diabetes	Yes	No
Kidney or bladder problems	Yes	No
Stomach ulcers	Yes	No
Hemorrhoids	Yes	No
Varicose Veins	Yes	No
Addison's disease	Yes	No
Varicose Veins	Yes	No
Any other condition which might adversely affect or be affected by testing protocols?	Yes	No
Are you currently pregnant?	Yes	No

Explain any Yes response _____

_____

16. Have you ever had any illness or injury other than those already noted that may affect your ability to participate in an exercise test? Yes No

(If Yes, please explain)

_____

_____

17. Do you now smoke? **Yes** No

18. If you are a smoker, indicate number smoked **PER DAY:**

Cigarettes: **40 or more** **20-39** **10-19** **1-9**

Cigars or pipes **ONLY:** **5 or more or any inhaled**
Less than 5, none inhaled

19. Do you exercise regularly? **Yes** No

20. How many days per week do you normally spend at least 20 minutes in moderate to strenuous exercise?

0 1 2 3 4 5 6 7 days per week

21. Please list the physical activities you participate in on a regular basis, e.g. walking, tennis, weight training. Please list all activities, tell how long you have been involved in the activity (months/years), and how many times per week you currently participate in the activity.

Activity:	How long:	# times/week
ex. walking	5 y	3
1.		
2.		
3.		
4.		
5.		
6.		

22. Weight now: _____lbs. One year ago: _____lbs.
Age 21: _____lbs.

23. Present weight_____

I understand that this information is confidential and is used solely to determine my eligibility to participate in research in the Functional Health Laboratory. I have answered each question truthfully and have no knowledge of other medical problems not disclosed on this form.

_____ _____
Signature/Date Witness/Date

Appendix C

Individual Subject Data

Physical characteristics of subjects

Group	Ss #	Height (cm)	Weight (kg)	Age (yrs)	Years resistance training	VO2max (ml/kg/min)	HRmax (bpm)	5 RM Bench press (kg)	5 RM Leg extension (kg)	% body fat	Lean body mass (kg)
CRT	23	175.00	93.98	29	7	49.5	173	113.64	125.00	10.2	84.39
CRT	30	168.28	76.14	22	3	44.1	188	115.91	104.55	18.3	62.20
CRT	33	182.88	102.84	30	18	53.1	185	140.91	113.64	12.2	90.31
CRT	287	184.15	90.11	27	4	49.5	190	102.27	93.18	12.4	78.94
CRT	369	181.61	84.77	26	3	na	196	75.00	90.91	na	84.77
CRT	400	180.34	93.75	24	3	44.6	190	86.36	105.23	11.3	83.13
CRT	425	184.15	89.43	29	3	43.3	na	77.27	115.91	15.5	75.61
CON	8	175.26	83.41	24	0	38.1	193	54.55	79.55	24.5	63.00
CON	31	180.34	84.20	22	0	50.4	186	56.82	93.75	10.7	75.19
CON	47	175.26	73.18	24	0	44.5	194	79.55	85.23	8.3	67.11
CON	55	173.99	66.14	21	0	37.5	194	54.55	51.14	15.1	56.15
CON	411	170.18	72.84	25	0	46.0	185	52.27	85.23	15.4	61.62
CON	435	171.45	71.82	30	0	50.4	174	63.64	75.00	14.0	61.79
CON	444	170.18	76.50	25	0	46.7	180	93.18	73.86	15.1	64.99

CRT = chronic resistance trained

CON = control

Carotid Sinus Mechanoreceptor Sensitivity

Group	Ss #	-12 mmHg CSP	-12 mmHg RR int	-24 mmHg CSP	-24 mmHg RR int	-36 mmHg CSP	-36 mmHg RR int	-48 mmHg CSP	-48 mmHg RR int
CRT	23	132.00	137.67	144.00	169.00	156.00	227.00	168.00	224.00
CRT	30	132.00	70.20	144.00	136.90	136.00	194.53	168.00	289.20
CRT	33	132.00	-138.60	144.00	-4.00	156.00	222.50	168.00	112.50
CRT	287	125.67	-41.50	137.67	48.17	149.67	137.17	161.67	123.50
CRT	369	118.33	111.83	130.33	142.50	142.33	129.38	154.33	205.62
CRT	400	139.33	15.00	151.33	-6.00	163.33	28.75	175.33	28.50
CRT	425	135.67	41.11	147.67	-22.00	159.67	56.25	171.67	152.33
CON	8	140.67	-10.83	152.67	25.17	164.67	81.00	176.67	155.00
CON	31	138.67	-85.53	150.67	10.17	162.67	16.17	174.67	-14.00
CON	47	137.67	47.33	149.67	85.17	161.67	216.67	173.67	242.00
CON	55	na	na	na	na	na	na	na	na
CON	411	139.67	74.00	151.67	130.50	163.57	164.50	175.67	189.80
CON	435	144.00	18.83	156.00	-64.67	168.00	-67.50	180.00	-72.78
CON	444	134.33	5.47	146.33	171.83	158.33	198.17	170.33	229.17

Pressures listed as XX mmHg represent neck chamber pressure
CSP = carotid sinus pressure, mmHg
RR int = change in R-R interval with stimulus, msec
CRT = chronic resistance trained
CON = control

Carotid Sinus Mechanoreceptor Sensitivity (continued)

Group	Ss#	-60 mmHg CSP	-60 mmHg RR int	+10 mmHg CSP	+10 mmHg RR int	+20 mmHg CSP	+20 mmHg RR int	+40 mmHg CSP	+40 mmHg RR int
CRT	23	180.00	342.00	110.00	-105.00	100.00	-47.67	80.00	-114.60
CRT	30	180.00	336.90	110.00	-38.80	100.00	-114.90	80.00	-117.60
CRT	33	180.00	227.33	110.00	-197.30	100.00	-170.00	80.00	-189.10
CRT	287	173.67	68.67	103.67	-73.83	93.67	-72.00	73.67	-119.80
CRT	369	166.33	179.17	96.33	25.17	86.33	-8.33	66.33	-10.67
CRT	400	187.33	55.50	117.33	-120.50	107.33	-97.50	87.33	-106.00
CRT	425	183.67	222.67	na	na	103.67	-194.60	83.67	-99.83
CON	8	188.67	159.50	118.67	-33.00	108.67	-27.50	88.67	-41.00
CON	31	186.67	101.47	116.67	-84.00	106.67	-58.00	86.67	-178.30
CON	47	185.67	220.67	115.67	-89.67	105.67	-97.00	85.67	-198.10
CON	55	na	na	na	na	na	na	na	na
CON	411	187.67	252.00	117.67	-29.33	107.67	-85.83	87.67	-48.50
CON	435	192.00	-4.53	114.67	-15.17	104.67	-50.17	84.67	-86.00
CON	444	182.33	238.67	112.33	-20.83	102.33	-33.00	82.33	-8.83

Pressures listed as XX mmHg represent neck chamber pressure
CSP = carotid sinus pressure, mmHg
RR int = change in R-R interval with stimulus, msec
CRT = chronic resistance trained
CON = control

LBNP data

Group	Ss#	LBNPmax (mm Hg)	LTI	Calf circumference @ rest, cm	Forearm circumference @ rest, cm	FBF @ rest	FBF @ 25% LBNPmax	FBF @ 50% LBNPmax	FBF @ 75% LBNPmax	FBF @ 100% LBNPmax
CRT	23	100	286	39.6	30.5	3.03	2.13	1.40	1.63	1.66
CRT	30	90	254	37.3	37.3	3.76	3.40	1.75	2.07	1.68
CRT	33	90	263	41.5	31.5	2.57	2.17	1.66	1.94	3.97
CRT	287	50	150	39.6	29.3	4.72	3.99	3.36	3.35	2.40
CRT	369	90	272	38.8	29.3	2.66	2.37	2.60	2.30	2.00
CRT	400	90	262	41.8	31.2	4.84	2.28	3.10	2.64	2.58
CRT	425	80	239	37.7	37.7	2.95	2.85	2.15	2.65	1.57
CON	8	60	170	35.4	28.5	2.28	2.98	2.48	2.01	1.88
CON	31	50	150	28.5	28.5	3.09	2.14	2.97	2.73	3.48
CON	47	60	178	38	29.4	2.84	2.22	2.41	2.53	3.67
CON	55	60	180	33.7	26.2	4.90	3.69	1.21	2.21	3.88
CON	411	80	222	36.2	27.5	3.32	1.08	2.33	1.13	3.44
CON	435	50	145	35.5	26.9	2.15	1.60	1.71	2.11	4.24
CON	444	60	181	37.3	29.2	2.12	1.76	1.83	1.74	2.01

LTI = LBNP tolerance index, mmHg• min

FBF = forearm blood flow, ml/100 cc tissue/min

CRT = chronic resistance trained

CON = control

LBNP data (continued)

Group	Ss#	HR @ rest	HR @ 25% LBNPmax	HR @ 50% LBNPmax	HR @ 75% LBNPmax	HR @ 100% LBNPmax	SBP @ rest	SBP @ 25% LBNPmax	SBP @ 50% LBNPmax	SBP @ 75% LBNPmax
CRT	23	43	53	54	75	99	105	96	103	92
CRT	30	67	63	79	83	107	118	123	104	115
CRT	33	51	53	72	81	109	124	119	109	102
CRT	287	60	64	78	70	82	116	113	102	108
CRT	369	56	61	75	85	103	118	112	97	100
CRT	400	54	64	72	90	115	134	142	106	107
CRT	425	55	54	74	82	112	140	127	120	112
CON	8	63	69	68	91	99	129	130	119	109
CON	31	56	54	51	71	85	131	132	122	116
CON	47	59	63	69	80	101	120	113	111	118
CON	55	66	64	94	92	110	133	137	123	103
CON	411	57	58	61	75	94	117	111	114	101
CON	435	51	51	63	72	64	134	120	118	119
CON	444	56	63	68	81	99	122	115	116	107

HR = heart rate, beats/min
SBP = systolic blood pressure, mmHg
CRT = chronic resistance trained
CON = control

LBNP data (continued)

Group	Ss#	SBP @ 100% LBNPmax	DBP @ rest	DBP @ 25% LBNPmax	DBP @ 50% LBNPmax	DBP @ 75% LBNPmax	DBP @ 100% LBNPmax	ΔLC @ 25% LBNPmax	ΔLC @ 50% LBNPmax	ΔLC @ 75% LBNPmax
CRT	23	89	47	60	66	65	59	1.31	1.25	2.24
CRT	30	84	65	67	61	72	61	3.06	4.51	6.23
CRT	33	97	73	66	71	70	73	0.50	1.41	2.41
CRT	287	106	67	72	71	74	69	1.06	1.36	1.85
CRT	369	92	62	63	63	64	70	na	na	na
CRT	400	92	62	60	71	63	66	na	na	na
CRT	425	94	84	71	94	84	61	0.27	0.75	1.33
CON	8	92	84	83	84	74	69	0.77	1.03	1.62
CON	31	118	71	72	60	65	88	na	na	na
CON	47	108	65	67	70	78	76	0.25	0.32	1.05
CON	55	110	75	63	70	76	65	0.23	0.22	0.35
CON	411	99	71	74	75	79	71	0.46	1.09	1.77
CON	435	123	71	72	63	55	68	0.40	0.59	0.77
CON	444	88	68	74	71	75	60	0.83	1.51	2.00

SBP = systolic blood pressure, mmHg
DBP = diastolic blood pressure, mmHg
ΔLC = leg (calf) circumference change, %

CRT = chronic resistance trained
CON = control

LBNP data (continued)

Group	Ss#	ΔLC @ 100% LBNPmax	MABP @ rest	MABP @ 25% LBNPmax	MABP @ 50% LBNPmax	MABP @ 75% LBNPmax	MABP @ 100% LBNPmax	FVR @ rest	FVR @ 25% LBNPmax	FVR @ 50% LBNPmax
CRT	23	3.19	66.33	72.00	78.33	74.00	69.00	21.89	33.80	55.95
CRT	30	5.88	82.67	85.67	75.33	86.33	68.67	21.99	25.20	43.05
CRT	33	3.45	90.00	83.67	83.67	80.67	81.00	35.02	38.56	50.40
CRT	287	2.47	83.33	85.67	81.33	85.33	81.33	17.65	21.47	24.21
CRT	369	na	80.67	79.33	74.33	76.00	77.33	30.33	33.47	28.59
CRT	400	na	86.00	87.33	82.67	77.67	74.67	17.77	38.30	26.67
CRT	425	1.89	102.67	89.67	102.67	93.33	72.00	34.80	31.46	47.75
CON	8	1.77	99.00	98.67	95.67	85.67	76.67	43.42	33.11	38.58
CON	31	na	91.00	92.00	80.67	82.00	98.00	29.45	42.99	27.16
CON	47	1.33	83.33	82.33	83.67	91.33	86.67	29.34	37.09	34.72
CON	55	1.81	94.33	87.67	87.67	85.00	80.00	19.25	23.76	72.45
CON	411	2.09	86.33	86.33	88.00	86.33	80.33	26.00	79.94	37.77
CON	435	6.70	92.00	88.00	81.33	76.33	86.33	42.79	55.00	47.56
CON	444	2.38	86.00	87.67	86.00	85.67	69.33	40.57	49.81	46.99

ΔLC = leg (calf) circumference change, %
MABP = mean arterial blood pressure, mmHg
FVR = Forearm vascular resistance, U

CRT = chronic resistance trained
CON = control

LBNP data (continued)

Group	Ss#	FVR @ 75% LBNPmax	FVR @ 100% LBNPmax
CRT	23	45.40	41.57
CRT	30	41.71	40.88
CRT	33	41.58	20.40
CRT	287	25.47	33.89
CRT	369	33.04	38.67
CRT	400	29.42	28.94
CRT	425	35.22	45.86
CON	8	42.62	40.78
CON	31	30.04	28.16
CON	47	36.10	23.62
CON	55	38.46	20.62
CON	411	76.40	23.35
CON	435	36.18	20.36
CON	444	49.24	34.49

FVR = Forearm vascular resistance, U
CRT = chronic resistance trained
CON = control

Relative Statistics

Ss#	23	30	33	287	369	400	425
Variable/pressure							
LC, % change							
0	0	0	0	0	.	.	0.00
-10	1.59	0.78	0.09	0.53	.	.	0.07
-20	1.27	1.96	0.22	1.06	.	.	0.27
-30	1.31	3.06	0.50	1.36	.	.	0.44
-40	1.27	3.72	0.72	1.85	.	.	0.75
LC, cm							
0	39.60	37.30	41.50	39.60	.	.	37.70
-10	40.23	37.59	41.54	39.81	.	.	37.73
-20	40.10	38.03	41.59	40.02	.	.	37.80
-30	40.12	38.44	41.71	40.14	.	.	37.87
-40	40.10	38.69	41.80	40.33	.	.	37.98
HR							
0	43	67	51	60	56	54	55
-10	45	60	52	61	55	52	58
-20	46	68	49	66	57	58	55
-30	50	69	54	72	62	62	56
-40	52	69	59	73	61	63	60
SBP							
0	105	118	124	116	118	134	140
-10	103	114	124	113	108	127	141
-20	103	116	119	118	105	120	134
-30	101	119	114	116	108	120	130
-40	101	114	119	110	104	117	134
DBP							
0	47	65	73	67	62	62	84
-10	46	64	62	66	66	66	80
-20	50	74	77	68	66	64	80
-30	63	65	69	53	64	59	80
-40	60	67	76	72	64	65	80
MABP							
0	66.33	82.67	90.00	83.33	80.67	86.00	102.67
-10	65.00	80.67	82.67	81.67	80.00	86.33	100.33
-20	67.67	88.00	91.00	84.67	79.00	82.67	98.00
-30	75.67	83.00	84.00	74.00	78.67	79.33	96.67
-40	73.67	82.67	90.33	84.67	77.33	82.33	98.00
FBF							
0	3.03	3.76	2.57	4.72	2.66	4.84	2.95
-10	2.10	2.06	2.37	4.61	2.49	2.56	3.11
-20	1.71	3.45	2.17	2.52	1.86	3.68	3.11
-30	1.80	1.72	3.18	3.50	1.55	2.53	2.98
-40	1.84	1.50	2.29	3.58	1.89	3.13	2.64
FVR							
0	21.89	21.99	35.02	17.66	30.33	17.77	34.80
-10	30.95	39.16	34.88	17.72	32.13	33.72	32.26
-20	39.57	25.51	41.94	33.60	42.47	22.46	31.51
-30	42.04	48.26	26.42	21.14	50.75	31.36	32.44
-40	42.04	48.26	26.42	21.14	50.75	31.36	32.44

Key

LC = leg circumference
HR = heart rate
SBP = systolic blood pressure
DBP = diastolic blood pressure
MABP = mean arterial blood pressure
FBF = forearm blood flow
FVR = forearm vascular resistance

Relative Statistics

Ss#	8	31	47	55	411	435	444
Variable/pressure							
LC, % change							
0	0.00	.	0.00	0.00	0.00	0.00	0.00
-10	0.61	.	-0.04	0.11	0.18	0.11	0.16
-20	0.77	.	0.25	0.23	0.46	0.40	0.83
-30	1.03	.	0.32	0.11	0.69	0.59	1.19
-40	1.32	.	0.62	0.22	1.09	0.77	1.51
LC, cm							
0	35.40	.	38.00	33.70	36.20	35.50	37.30
-10	35.62	.	37.98	33.74	36.27	35.54	37.36
-20	35.67	.	38.10	33.78	36.37	35.64	37.61
-30	35.76	.	38.12	33.74	36.45	35.71	37.74
-40	35.87	.	38.24	33.77	36.59	35.77	37.86
HR							
0	63	56	59	66	57	51	56
-10	64	52	58	65	57	52	56
-20	69	58	61	63	55	55	61
-30	69	55	70	67	60	63	65
-40	73	66	71	85	65	69	68
SBP							
0	129	131	120	133	117	134	122
-10	131	131	118	139	113	124	119
-20	139	131	114	137	113	112	112
-30	121	125	118	131	115	118	113
-40	118	119	115	128	114	113	114
DBP							
0	84	71	65	75	71	71	68
-10	82	64	69	72	72	72	66
-20	83	72	68	68	77	72	66
-30	79	63	68	63	75	73	71
-40	80	74	69	69	84	65	69
MABP							
0	99.00	91.00	83.33	94.33	86.33	92.00	86.00
-10	98.33	86.33	85.33	94.33	85.67	89.33	83.67
-20	101.67	91.67	83.33	91.00	89.00	85.33	81.33
-30	93.00	83.67	84.67	85.67	88.33	88.00	85.00
-40	92.67	89.00	84.33	88.67	94.00	81.00	84.00
FBF							
0	2.28	3.09	2.84	4.90	3.32	2.15	2.12
-10	2.35	2.87	2.37	4.35	2.79	1.56	2.40
-20	2.27	3.46	2.75	3.67	1.83	1.60	1.96
-30	2.39	2.61	2.41	2.82	2.36	1.97	2.04
-40	2.35	2.47	2.31	.	2.24	2.06	1.97
FVR							
0	43.42	29.45	29.34	19.25	26.00	42.79	40.57
-10	41.84	30.08	36.01	21.69	30.70	57.26	34.86
-20	44.79	26.49	30.30	24.80	48.63	53.33	41.50
-30	38.91	32.06	35.13	30.38	37.43	44.67	41.67
-40	38.91	32.06	35.13	.	37.43	44.67	41.67

Key

LC = leg circumference
HR = heart rate
SBP = systolic blood pressure
DBP = diastolic blood pressure
MABP = mean arterial blood pressure
FBF = forearm blood flow
FVR = forearm vascular resistance

Vita

Sharon Boon was born in the Delta Quadrant (think: Star Trek), and has been an occupant of Earth since 1969 (don't ask when she was born). She currently is completing her mission of learning more about this planet's educational systems. She started an undergraduate career in Architecture at Clemson University, and completed her undergraduate career as a Physical Education major at Winthrop University.

During her tenure here, she has become certified by the American College of Sports Medicine (ACSM) as a Health Fitness Instructor, by the National Strength and Conditioning Association (NSCA) as a Certified Strength and Conditioning Specialist and Personal Trainer, by the American Council on Exercise as a Personal Trainer, and by the Aerobics and Fitness Association of American as an Aerobics and STEP Instructor. She is also a member of the ACSM, the NSCA, and the American Alliance for Health, Physical Education, Recreation and Dance.

Sharon is owned by her cat, Smudge (also from the Delta Quadrant), and looks forward to a prolonged stay in this planetary system prior to returning home and heading off to other new, unexplored territories.