RESISTANCE EXERCISE TIMING EFFECTS ON BLOOD PRESSURE

A Thesis
by
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Submitted to the Graduate School
at Appalachian State University
in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE

May 2014
Department of Health, Leisure & Exercise Science

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Abstract

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Following aerobic exercise, an induced post-hypotension helps lower blood pressure via systemic vasodilatation and baroreflex sensitivity alteration. Resistance exercise has been shown to elicit increases in arterial stiffness leading to higher blood pressure readings in individuals that resistance train. Recent research has shown that resistance exercise can lower blood pressure, yet little is known regarding the best time to complete resistance exercise for the greatest nocturnal benefit; therefore, the purpose of this study is to evaluate the effects of resistance exercise timing on blood pressure. We hypothesized greater nocturnal blood pressure dipping after resistance exercise performed at 7 a.m. METHODS: 25 healthy, young adults completed the study. Measurements of VO2max, 10-RM, and control blood pressures were established before commencement of resistance exercise. Subjects completed 3 randomized visits at 7 a.m., 1 p.m., and 7 p.m., where they performed 9 resistance exercises using machine weights at 65% of their 10-RM for 3 sets of 10 repetitions for a total exercise time of 30 minutes per visit. Blood pressure data was recorded using an Oscar2 Ambulatory Blood pressure monitor after VO2max testing and after each resistance exercise visit. RESULTS: Blood pressure did not vary significantly between resistance exercise sessions. Overall, resistance exercise has shown no deleterious effects on myocardial work demand or BP responses; however, nocturnal systolic blood pressure was elevated after 7a.m. resistance exercise in both men and women and more so for men. Further, nocturnal systolic blood pressure was lower in women after 1p.m. resistance exercise than 7p.m. CONCLUSION: Resistance exercise training at 7 a.m. may elicit increases in BP, especially in men, yet resistance exercise at 1p.m. improved the BP profiles of subjects greater than other exercise times.

Key words: Stress hormones; training; baroreceptors; nocturnal dipping

Acknowledgments

For their guidance, wisdom, and advice in this process, I would like to thank my thesis committee members: Dr. Scott R. Collier, Dr. N. Travis Triplett and Dr. Steven R. McAnulty. I would also like to thank my fellow graduate student and thesis partner Jessica R. Alley for her tremendous help, insight, and diligence. Without their help, this thesis would never have come to fruition. Gratitude is also due to the Appalachian State University Office of Student Research for funding this research.

Dedication

This work is dedicated to my father, who taught me never to quit or give up on anything I start, even in the face of adversity.

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Foreword

Chapters 1- 4 and the references of this thesis will be submitted to The Journal of Strength And Conditioning Research, an international peer-reviewed journal owned by The Lippincott Williams & Wilkins Company and published by The Kivmars Bowling Press; it has been formatted according to the style guide for that journal.

INTRODUCTION

Hypertension is defined as an individual having a systolic blood pressure of or above 140 mm Hg and diastolic blood pressure of or above 90 mm Hg (11). While hypertension is a modifiable risk factor of cardiovascular disease, if left unchecked, it can progress into serious cardiovascular conditions such as congestive heart failure, stroke, and coronary artery disease (31, 32). Clinically, the trend is to prescribe anti-hypertensive medications; however, a much more efficient and cost effective treatment for high blood pressure can be lifestyle intervention, such as exercise (28, 13). Regular exercise can match the power of pharmacologics, and when combined with a healthy diet, exercise is capable of exceeding the effects of medication on hypertension (33, 4, 22, 26). Good sleep quality allows for the resetting of the set point of the baroreceptors, which lowers resting blood pressure (27). It is well known that aerobic exercise effectively lowers resting blood pressure through improving sleep quality, yet little is known about the effects of resistance exercise on sleep quality and blood pressure.

In spite of recent advances in medicine and healthcare, Cardiovascular Disease (CVD) remains one of the largest health issues in our nation. Hypertension is one of the most common forms of CVD, and while males 45 years of age and females 55 years of age and older are at the most risk for developing CVD, cases of hypertension have been recorded in people as young as 15 to 20 years old (26). Hypertension is a progressive disease that can lead to more serious forms of CVD, such as atherosclerosis. Hypertension is defined as systolic pressure above 140 mm Hg and diastolic pressure above 90 mm Hg. The increased pressure adds to the strain sustained by the walls of blood vessels, which can injure the blood vessel and lead to the development of an atheroma (44). An atheroma formation causes blood vessel occlusion and death of tissue downstream from the blockage, which can cause a heart attack if an atheroma forms in the cardiac vasculature. Hypertension also stimulates increased blood clotting, adding to CVD potential to be fatal (20). The negative effects of hypertension can be treated through medications and diet; however, daily exercise has been proven to vastly improve blood pressure (34), and decrease the risk of developing CVD.

Hypertension Reduction via Aerobic Exercise

Daily aerobic exercise performed at certain times of the day has positive effects on blood pressure and can help reduce hypertension (23). Specifically, it has been reported that regular aerobic exercise between 7 and 8 o'clock in the morning conveys the most benefit (24). Aerobic exercise in these early morning hours resulted in decreased blood pressure and increased aerobic fitness because of a phenomenon called, "morning surge." Morning surge is a rise in blood pressure, especially in the early morning hours, that occurs upon waking (23). When combined with aerobic exercise between 7 and 8 o'clock a.m., morning surge causes a spike in blood pressure that triggers baroreceptors to raise blood pressure set point and lower resting heart rate. This effect results in lowered blood pressure over time as well as a lower resting heart rate, which ultimately places less strain on the heart allowing patients to live longer (38).

Blood pressure is lowered via a resetting of baroreceptors, thus reducing the hypertensive response (42, 16). Exercise acutely elevates blood pressure past the baroreceptor set point, stimulating baroreceptors to cause vasodilation and lower blood pressure (28). Following exercise, an exercised induced post-hypotension lowers the baroreceptor set point, in turn increasing baroreceptor sensitivity to blood pressure changes (19). Thus, baroreceptors become capable of regulating blood pressure more effectively in future exercise (1). During sleep, the baroreceptors are reset during a process called "nocturnal blood pressure dipping," which takes place during restorative phases of sleep such as deep sleep and REM sleep (27). Dipping is classified as a 10-20% drop in blood pressure from daytime levels and has been correlated to a reduction in pre-hypertension (40, 45).

Poor sleep is characterized by spending less time in the deep restorative stages of sleep, waking frequently, or staying awake longer once awake (45). Less time spent in deep sleep reduces dipping, discouraging blood pressure resetting (14, 47). Therefore, individuals that experience poor sleep present with an increased risk of pre-hypertension and Cardiovascular Disease (5, 15, 21). Regular exercise has been shown to result in better sleep quality, increasing the number of sleep cycles and time spent in deep restorative sleep (48). Historically, regular aerobic exercise is capable of increasing the number of sleep cycles and the time spent in restorative sleep (37). Furthermore, recent research has shown that the timing of aerobic exercise throughout the day is significant in conveying the most benefit to pre-hypertension (6). In fact, aerobic exercise performed at 7 a.m. is capable of improving blood pressure, thereby reducing hypertension, without the aid of pharmacologics and increasing time spent in the restorative cycles of sleep (12).

While aerobic exercise is becoming the primary recommendation for non-pharmacological means of reducing pre-hypertension (28, 35), there is a paucity of literature investigating the benefits of the timing of resistance exercise on sleep architecture (25). Recent studies have investigated the effects of resistance exercise on hypertension and the capability of regular resistance exercise to reduce blood pressure (43, 17). Tibana et al. investigated the effects of resistance exercise on hypertension in overweight, obese post-menopausal women. A recent study investigated the causal mechanism of resistance exercise and how it may reduce blood pressure in older adults with hypertension and pre-hypertension and concluded it may result in the lowering of arterial reservoir pressure. Collectively, it has been repeatedly shown that resistance exercise can lower blood pressure (43, 17), especially in those individuals with elevated levels.

The timing of resistance exercise may contribute to the beneficial effects of restorative sleep, yet to our knowledge, no research has been published investigating the effects of resistance exercise timing throughout the day on pre-hypertension and sleep cycles. Therefore, the purpose of this study is to evaluate the effects of resistance exercise during different times of the day on blood pressure during wake and sleep. We hypothesize that subjects engaging in resistance exercise at 7 a.m. will experience the greatest reduction in blood pressure.

Further Research

This study will provide a solid foundation on which to build future research on the effects of resistance training on hypertension. For example, the effects of resistance training during different times throughout the day have not yet been explored, and this type of work may help determine at what time of the day the most benefit to reducing hypertension is obtained. Although the beginnings of hypertension and atherosclerosis can be seen as early as in the fetal stages due to the mother's poor diet, the majority of hypertensive cases are observed in middle to older aged males and females (18). This population often suffers from mobility problems as well as joint issues, restricting them to low impact exercise such as swimming. Based on this specific population, future research could explore the effects, if any, that resistance training in water has on blood pressure and hypertension since water exercise is low impact on joints.

Hypertension and CVD have become more prevalent and lead to increasing cases of hospitalization and death, therefore, any research resulting in novel methods of combating this disease would be practical

METHODS

Experimental Approach to the Problem

Although aerobic exercise is a prominent non-pharmacological method of reducing blood pressure and improving risk of hypertension, it still has shortcomings. The majority of pre-hypertensive and hypertensive populations has obesity and orthopedic problems and may be unable to perform extended periods of aerobic exercise; therefore, it may be more feasible to have them do shorter, resistance exercise bouts. Ultimately, any research done suggesting that resistance exercise creates improvements in subjects' blood pressures would be significant to the ever-growing pre-hypertensive and hypertensive population. Specific time epochs of resistance exercise may provide greater utility to a pre-hypertensive and hypertensive population since an individual may derive greater hemodynamic and sleep benefits within the same time period, which may reduce the healthcare costs and dependence on pharmocologics.

Subjects

A total of 25 (M=11; F=14) non-smoking, sedentary to recreationally active, college-aged (18-25 years) subjects with no orthopedic limitations to exercise participated in this study. Subjects were recruited from the student population at Appalachian State University in Boone, North Carolina. Out of the 25 that started the study, 24 completed it. One subject dropped out of the study due to time constraints. Participants were classified as sedentary to recreationally active based on their exercise habits for 6 months prior to the study (no more than 2 hours of structured exercise of any kind per week to be recreationally active). None of the subjects were on long-term prescription medications or had been diagnosed with any chronic illness. They were instructed to refrain from alcohol, tobacco, and caffeine while participating in the study. The present study was subjected to a full board review and was approved by the Institutional Board at Appalachian State University in Boone, N.C. (IRB #13-0255). Appropriate informed consent was obtained, as pursuant to law, before each subject began the study. The parameters of the study complied with and were approved by the Appalachian State University at Boone institutional review board.

Procedures

Subjects attended five visits to complete the study. The first visit consisted of participants signing informed consent, learning methods of data collection, resting blood pressure measurements, and VO2max testing. Resting blood pressure measurements were recorded after subjects sat quietly for five minutes and completed informed consent and health history forms. The VO2max testing was conducted using a modified Ballke treadmill test in order to assess baseline fitness levels of participants.

The second visit took place the very next day and included establishing a 10-RM on each resistance exercise and familiarization with the weight machines. Visits 3, 4, and 5 occurred at either 7 a.m., 1 p.m. or 7 p.m. based on a randomized schedule. On the third, fourth, and fifth visits, participants engaged in a routine of nine resistance exercises using machine weights. Subjects performed each resistance exercise at 65% of their 10-RM for 3 sets of 10 repetitions for a total exercise time of 30 minutes.

An Oscar 2TM ambulatory blood pressure cuff was used to monitor blood pressure up to 24 hours post exercise (SunTech Medical Oscar 2, Morrisville, NC). Blood pressure was collected during each subsequent session while participants were performing resistance exercise.

Statistical Analyses

Sample size calculations were performed using the means and standard deviations from a previous study conducted in the laboratory with G*Power Descriptive statistics were determined with univariate calculations for means and Standard Errors. A 1x3 rmANOVA was employed to determine differences between exercise times with an alpha-level set at $p<0.05$. It was determined that 25 subjects were needed to reach significance with a power of 0.8. Statistical Software for the Social Sciences (SPSS, Chicago, IL) version 19.0 was used.

RESULTS

Descriptive statistics, overall blood pressures, and nocturnal blood pressures for all subjects in the study are presented in Table 1. Overall blood pressure did not change in either sex after resistance exercise intervention ($p>0.05$) [Table 1]. Mean nocturnal systolic blood pressure was elevated in both sexes after resistance exercise at 7 a.m., but more so for males ($p<0.05$) [Figure 1]. Mean nocturnal systolic blood pressure was lower for women after resistance exercise at 1 p.m. than after resistance exercise at 7 p.m. [Figure 1]. Neither overall nor nocturnal diastolic blood pressures changed significantly for either sex following the resistance exercise intervention ($p>0.05$) [Table 1]. Neither males nor females experienced a significant dip (BP dip>10% daytime levels) in nocturnal systolic or diastolic blood pressure from control blood pressure measurements [Figure 2].

DISCUSSION

Our data indicate resistance exercise performed at 7 a.m. increased nocturnal systolic blood pressure in both men and women. Conversely, Cartner et al. (6) showed that aerobic exercise at 7 a.m. contributed the greatest benefit to nocturnal systolic blood pressure dipping. Their group speculated their results could have been attributed to aerobic exercise attenuating the expression of the circadian release of stress hormones. Our divergent results could be attributed to high levels of stress hormone upon walking; however, only men showed a significant difference in nocturnal systolic blood pressure rise from control to post-7 a.m. resistance exercise. Therefore, the present study suggests that 7 a.m. resistance exercise is not beneficial for augmenting the nocturnal systolic blood pressure dip for men. Whereas, resistance exercise at 1 p.m. was better for nocturnal systolic blood pressure than resistance exercise at 7 a.m.

The American College of Sports Medicine has not recommended resistance exercise as a stand-alone form of exercise training due to the mixed effects on blood pressure. Since the resistance encountered within the lumen determines the level of pressure, any change in the vessels distensibility will have the ultimate effect on the cardiovascular pressure. It has been shown that resistance exercise increases heart rate and arterial stiffness in men while there are several studies that show the converse of this in women (8, 9, 10, 36).

The data from this study will lend utility to the field such that resistance exercise does not show deleterious effects on nocturnal blood pressure and may be safe to prescribe to healthy, normotensive individuals. The caution for the prescription of early morning resistance training may exist; however, more research during this epoch of time is needed for such a conclusion to be drawn. In fact, the present study further affirms recent research and the supposition that resistance exercise acts to augment the beneficial effects of aerobic exercise on blood pressure.

The circadian regulation of blood pressure is partially controlled via hormonal influences and sleep is one of the biggest secretagogues known. It is well known that the early morning hours, when sleep cycles the awakening time periods, there is an augmented release of stress hormones. More specifically, it is well documented that stress hormones, such as cortisol are increasingly elevated in the early morning, called Cortisol Awakening Response (CAR). In a clinical population of rehabilitation patients, the mean value for cortisol morning rise was calculated to be 186% (41). Further, Clow et al. (7) and Shibuya et al. (39) individually have demonstrated that elevated CAR is associated with impaired physical health. Wust et al. (47) showed a mean cortisol increase of 50% from control levels as early as 30 minutes after waking. The same study also suggested that men and women experience almost identical elevations in cortisol levels upon waking. However, men exhibited a significantly delayed decrease in cortisol levels after waking, suggesting that stress hormones in men remain elevated after waking (47).

Further, it has been shown that cardiovascular related deaths occur at greater frequencies in the morning hours as opposed to any other epoch of time throughout the day. Muller et al. (30) reported an increased incidence of sudden cardiac death between the hours of 7 a.m. and 11 a.m. A strong positive correlation exists between the timing of day of sudden cardiac death and nonfatal myocardial infarction and instances of myocardial ischemia (30). Early morning waking has also been correlated to increased frequency of thrombotic processes leading to acute myocardial infarction, sudden cardiac death, and stroke (2). Andreotti et al. (2) suggests that possible early morning changes in blood fibrinolytic activity has the ability to disrupt the hemostatic equilibrium, pushing it toward thrombosis. These data combined with our outcome that early morning resistance exercise is not beneficial for male nocturnal systolic blood pressure may not be a favorable combination. In fact, our results, when combined with aforementioned stress hormone research, may be enough to suggest that early morning resistance exercise potentially exacerbates early morning cardiovascular events, such as acute myocardial infarction, and myocardial ischemia. Further study of the physiologic changes occurring in the morning, and especially with resistance exercise in the early morning hours may provide new information, thereby leading to further understanding and possible prevention of cardiac related death, as well as means of improving cardiovascular health.

Limitations: This study was limited by the number of subjects included. Increasing the number of participants would also increase the power of the statistics used and result in significant sex differences in blood pressure. Also, the present study did not time the dates of the resistance exercise with the female participant's menstrual cycle. There were no differences in overall blood pressure in either men or women following resistance exercise at different times of day. This suggests that resistance exercise overall is not detrimental to blood pressure levels.

PRACTICAL APPLICATIONS

Resistance exercise performed at different times of day did not lower overall or nocturnal blood pressure; however, there were sufficient data to suggest that the best time of day for women to resistance train is 1 p.m. Also, the present study found that resistance training at 7 a.m. has negative effects on nocturnal systolic blood pressure for both men and women, but more so for men. It is well known that this epoch of time in the early morning is when the incidence of myocardial infarctions in the male population is greatest, making resistance exercise a potential contraindication in a cardiovascular disease population. It should be noted that resistance exercise is not detrimental to overall blood pressure in that it does not significantly increase blood pressure both during and following a bout of moderate intensity exercise.

The present study's results have real world implications, which necessitate further investigation. Future research on resistance exercise effects on blood pressure in adults with scheduled and unscheduled work hours could refine the prescription of exercise as non-pharmacologic means of hypertension treatment. Specifically, there is a potential abundance of data that could be collected on the effects of resistance exercise on blood pressure in firefighters (unscheduled work hours) and police officers (scheduled work hours). A better understanding of exercise prescription for diseased and healthy populations alike is a promising means of improving quality of health care and reducing its cost.

REFERENCES

1) Alnima T, S. I., De Leeuw PW, Winkens B, Jongen-Vancraybex H, Tordoir JH, Schmidli J, Mohaupt MG, Allemann Y, Kroon AA. Sustained acute voltage-dependent blood pressure decrease with prolonged carotid baroreflex activation in therapy-resistant hypertension. J Hypertens. 2012. 30(8): 1665-1670.

2) Andreoetti F, et al. Major circadian fluctuations in fibrinolytic factors and possible relevance to time of onset of myocardial infarction, sudden cardiac death and stroke. The American Journal of Cardiology. Volume 62, Issue 9, 15 September 1988, Pages 635–637.

3) Becton LJ, S. I., Flynn JT. Hypertension and obesity: epidemiology, mechanisms and clinical approach. Indian J Pediatr. 2012. 79(8): 1056-1061.

4) Brown RE., B.R., McKenna JT., Strecker RE., McCarley RW. Control of sleep and wakefulness. Phsyiol Rev. 2012. 92(3): 1087-187.

5) Buxton OM, and Marcelli E. Short and long sleep are positively associated with obesity, diabetes, hypertension, and cardiovascular disease among adults in the United States. Soc. Sci. Med. 71(5): 1027-36.

6) Cartner BW, Fairbrother KR, Triplett NT, Morris DM, and Collier SR. The Effects of Aerobic Exercise Timing on Nocturnal Blood Pressure Dipping in PreHypertensive Individuals. Abstract.

7) Clow A, et al. Day differences in the cortisol awakening response predict day differences in synaptic plasticity in the brain. Stress. 2014 May;17(3):219-23. doi: 10.3109/10253890.2014.905533. Epub 2014 Apr 7.

8) Collier SR, *Diggle, MM, *Heffernan KS, *Kelly EE, *Tobin MM, Fernhall B. Changes in Arterial Distensibility and Flow Mediated Dilation Following Acute Resistance vs. Aerobic Exercise. Journal of Strength and Conditioning Research. 2010; 24(10):2846-52.

9) Collier SR, Frechette V, Sandberg, K, *Schafer P, Ji H., Smulyan H., Fernhall B. Sex Differences in resting hemodynamics and vascular stiffness following 4 weeks of exercise training. Biol Sex Differ. 2011; 2(1):9

10) Collier SR, Kanaley JA, Carhart Jr., Frechette V, *Tobin MM, *Hall AK, *Luckenbaugh AN, R., Fernhall B. Hemodynamic and vascular remodeling following aerobic compared to resistance training in hypertensive individuals. Journal of Human Hypertension. 2008; 22(10):678-86

11) Collier SR, Landram MJ. Treatment of prehypertension: lifestyle and/or medication.Vasc Health Risk Manag. 8: 613-619.

12) Collier SR, Morris D, Dickinson D, Curry CD, Cartner B, and Fairbrother K. Exercise Timing Effects on Sleep and Nocturnal Blood Pressure in Pre-Hypertensives.

13) Davis JT, P.D., Khandrika S, Fung MM, Milic M, O'Connor DT. Central Hemodynamics in Prehypertension: Effect of the B-Adrenergic Antagonist Nebivolol. J Clin Hypertens (Greenwich). 15(1): 69.

14) Eguchi K, Pickering TG, Schwartz JE, Hoshide S, Ishikawa J, Ishikawa S, Shimada K, and Kario K. Short Sleep duration as an independent predictor of cardiovascular events in Japanese patients with hypertension. Arch Intern Med. 2008; 168(20):2225-31.

15) Franklin PJ, Green DJ, and Cable NT. The influence of thermoregulatory mechanisms on post-exercise hypotension in humans. J Physiol. 1993;470:231-41.

16) Grassi G, S. G., Brambilla G, Bombelli M, Dell'Oro R, Gronda E, Mancia G. Novel antihypertensive therapies: renal sympathetic nerve ablation and carotid baroreceptor stimulation. Curr. Hypertens Rep. 2012. 14(6): 567-572.

17) Heffernan KS, Yoon ES, Sharman JE, Davies JE, Shih YT, Chen CH, Fernhall B, Jae SY. Resistance exercise training reduces arterial reservoir pressure in older adults with prehyptertension and hypertension. Hypertens Res. 2012.

18) Higashi, et al. 2012. Endothelial Function and Oxidative Stress in Renovascular Hypertension. N Engl J Med 2002; 346:1954-1962 June 20, 2002 DOI: 10.1056/NEJMoa01359.

19) Hosokawa K, I.T., Tobushi T, Sakamoto K, Onitsuka K, Sakamoto T, Fujino T, Saku K, Sunagawa K. Bionic baroreceptor corrects postural hypotension in rats with impaired baroreceptor. Circulation. 2012. 126(10): 1278-1285.

20) Iwata, et al. 2012. Higher ambulatory blood pressure is associated with aortic valve calcification in the elderly: a population-based study. Hypertension. 2013 Jan;61(1):55-60. doi: 10.1161/HYPERTENSIONAHA.112.202697. Epub 2012 Nov 12.

21) Javaheri S, Storfer-Isser A, Rosen CL, and Redline S. Sleep quality and elevated blood pressure in adolescents. Circulation. 2008;118(10):1034-40.

22) Jones DE, C. K., Bleich SN, Cooper LA. Patient trust in physicians and adoption of lifestyle behaviors to control high blood pressure. Patient Educ Couns. 2012. 89(1): 57-62.

23) Jones, H., K. George, et al. (2008). Effects of time of day on post-exercise blood pressure: circadian or sleep-related influences? *Chronobiol Int 25(6*), 987-998.

24) Jones, H., C. Pritchard, et al. (2008). The acute post-exercise response of blood pressure varies with time of day. *Eur J Appl Physiol 104(3*), 481-489.

25) Kubitz KA, Landers DM, Petruzzello SJ, and Han M. The effects of acute and chronic exercise on sleep. A meta-analytic review. Sports Med. 1996;21(4):277-91.

26) Laskey W, S. S., Wells C, Lueker R. Improvement in arterial stiffness following cardiac rehabilitation. Int. J Cardiol. 2012.

27) Loredo JS, Nelesen R, Ancoli-Israel S, and Dimsdale JE. Sleep quality and blood pressure dipping in normal adults. Sleep.2004;27(6):1097-103.

28) MacDonald JR, MacDougall JD, and Hogben CD. The effects of exercise duration on post-exercise hypotension. J Hum. Hypertens. 2000;14(2):125-9.

29) Michalska, et al. 2012. Selected atherosclerosis risk factors in youth aged 13-15 years. Postepy Hig Med Dosw (Online). 2012 Sep 11;66:647-54.

30) Muller JE, et al. Circadian variation in the frequency of sudden cardiac death. Circulation. 1987; 75: 131-138 doi: 10.1161/01.CIR.75.1.131.

31) Ong KL, Cheung BM, Man YB, Lau CP, and Lam KS. Prevalence, awareness, treatment, and control of hypertension among United States adults 1999-2004. Hypertension. 2007;49(1):69-75.

32) Park S, Jastremski CA and Wallace JP. Time of day for exercise on blood pressure reduction in dipping and nondipping hypertension. J Hum Hypertens. 2005;19(8):597-605.

33) Pal GK, Pal P, Nanda N, Amudharaj D, Adithan C. Cardiovascular dysfunctions and sympathovagal imbalance in hypertension and prehypertension: physiological perspectives. Future Cardiol. 9(1): 53-69.

34) Pedrinazzi, C., O. Durin, et al. (2012). [Competitive sports and leisure-time physical activity in patients with coronary heart disease]. *G Ital Cardiol (Rome) 13(10)*, 123-127.

35) Pescatello LS, Franklin BA, Fagard R, Farquar WB, Kelley GA, and Ray CA. American College of Sports Medicine position stand. Exercise and Hypertension. Med. Sci. Sports Exerc. 2004;36(3):533-53.

36) Rakowbowchuk et al. Effect of whole body resistance training on arterial compliance in young men.; Exp Physiol. 2005 Jul;90(4):645-51.

37) Reid KJ, Baron KG, Lu B, Naylor E, Wolfe L, and Zee PC. Aerobic exercise improves self-reported sleep and quality of life in older adults with insomnia. Sleep Medicine. 2010;9:934-40.

38) Richard, K.E. 2012. Cardiovascular Physiology Concepts.

39) Shibuya I, et al. High correlation between salivary cortisol awakening response and the psychometric profiles of healthy children. Biopsychosoc Med. 2014 Mar 14;8(1):9. doi: 10.1186/1751-0759-8-9.

40) Smolensky MH, Hermida RC, Castriotta RJ, and Portaluppi F. Role of sleep-wake cycle on blood pressure circadian rhythms and hypertension. Sleep Med. 2007;8(6):668-80.

41) Storetvedt K, Garde AH. Can morning rise in salivary cortisol be a biological parameter in an occupational rehabilitation clinic? A feasibility study. Rehabil Res Pract. 2014;2014:793641. doi: 10.1155/2014/793641. Epub 2014 Mar 5.

42) Takahashi H. Upregulation of the Renin-Angiotensin-aldosterone-ouabain system in the brain is the core mechanism is the genesis of all types of hypertension. Int. J Hypertens. 2012.

43) Tibana, R. A., G. B. Pereira, et al. Acute Effects of Resistance Exercise on 24-h Blood Pressure in Middle Aged Overweight and Obese Women. Int J Sports Med.

44) Tuttolomondo, et al. 2012. Atherosclerosis as an inflammatory disease. Curr Pharm Des. 2012;18(28):4266-88.

45) Verdecchia P, Angeli F, and Cavallini C. Ambulatory blood pressure for cardiovascular risk stratification. Circulation. 2007;115(16):2091-3.

46) Waterhouse J., F.Y., Morita T. Daily rhythms of the sleep-wake cycle. J Physiol Anthropol. 2012. 31(5).

47) Wust S, Wolf J, Hellhammer DH, Federenko I, Schommer N, Kirschbaum C. The cortisol awakening response - normal values and confounds. Noise Health 2000;2:79-88.

48) Yilmaz MB, Yalta K, Turgut OO, Yilmaz A, Yucel O, Bektasoglu G, and Tandogan I. Sleep quality among relatively younger patients with initial diagnosis of hypertension: dippers versus non-dippers. Blood Press. 2007;16(2):101-5.

49) Youngstedt SC, and Kline CE. Epidemiology of exercise and sleep. Sleep & Biological Rhythms. Wiley-Blackwell; 2006, pp. 215-21. :74.

ACKNOWLEDGMENTS: This study was partially funded by the Office of Student Research at Appalachian State University in Boone North Carolina (OSR102230 awarded to John Mazzochi.

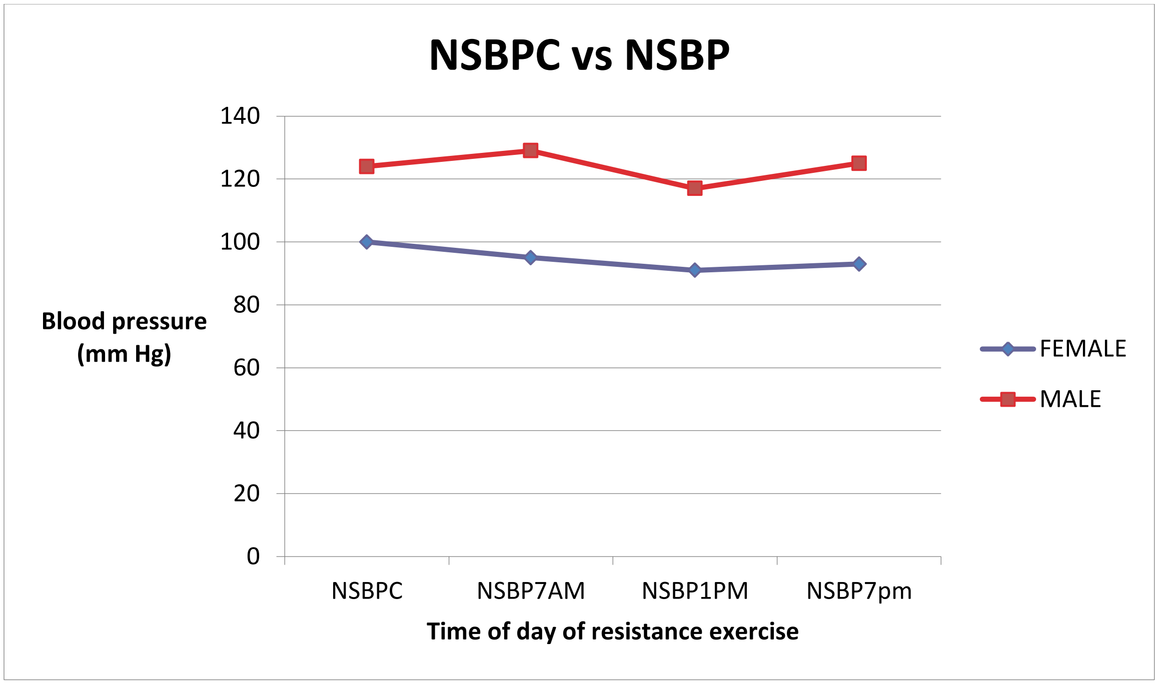

Figure 1. Average nocturnal control systolic blood pressure vs. average systolic blood pressure for males and females.

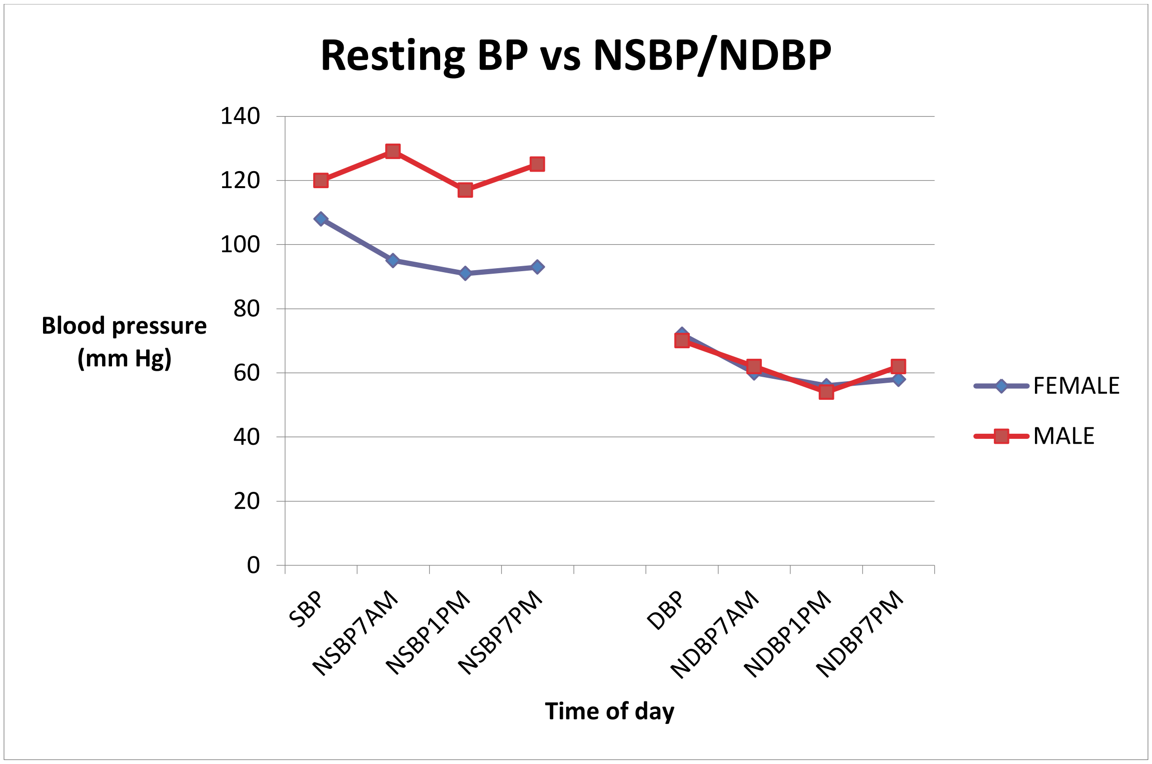

Figure 2. Visit 1 average resting blood pressure vs. average nocturnal systolic and diastolic blood pressure for males and females.

Descriptive Statistics

	N	Minimum	Maximum	Mean		Std. Deviation
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
Age	25	18	22	19.76	.260	1.300
Height	25	58.50	75.00	67.3400	.79450	3.97248
Weight	25	60.10	231.20	158.3112	7.93015	39.65077
BIA	25	11.20	45.50	23.0800	1.90838	9.54188
Hydration	25	3	8	5.24	.260	1.300
ControlSBP	25	104	132	118.16	1.669	8.345
ControlDBP	25	52	88	70.96	2.017	10.085
VO2	25	21.00	55.30	37.7400	1.51923	7.59616
OverallSBPC	25	98.00	140.00	115.2800	2.71509	13.57547
OverallSBP7am	25	98	164	119.20	3.422	17.108
OverallSBP1pm	23	94	156	116.96	3.605	17.288
OverallSBP7pm	24	96	170	118.17	3.685	18.052
OverallDBPC	25	46.00	74.00	59.6000	1.45144	7.25718
OverallDBP7am	25	48	94	60.00	2.043	10.214
OverallDBP1pm	23	46.00	74.00	58.6957	1.49629	7.17594
OverallDBP7pm	24	48.00	94.00	60.0000	1.90347	9.32505
NSBPC	25	98.00	140.00	115.2000	2.67333	13.36663

NSBP7am	24	100.00	162.00	120.1667	3.38992	16.60714
NSBP1pm	23	94.00	154.00	116.8696	3.56714	17.10743
NSBP7pm	24	96.00	170.00	118.1667	3.71428	18.19619
NDBPC	25	46.00	74.00	59.5200	1.45730	7.28652
NDBP7am	24	46.00	92.00	60.5833	2.05884	10.08622
NDBP1pm	23	44.00	72.00	58.0000	1.49307	7.16050
NDBP7pm	24	50.00	94.00	60.1667	1.89169	9.26737
Valid N (listwise)	23					

Table 1. Descriptive statistics, overall blood pressure and nocturnal blood pressure of all subjects.

Vita

John William Mazzochi was born in Stockton, California, to Richard and Paula Mazzochi. He graduated from West Florence High School in South Carolina in May 2007. The following autumn, he entered the University Of South Carolina to study Biology and Exercise Science; and in May 2012, he was awarded two Bachelor of Science degrees. In the fall of 2012, he accepted a candidacy for a Master's Degree in Exercise Science at Appalachian State University and began study toward a Master of Science degree. The M.S. was awarded in May 2014.

Mr. Mazzochi has over two years experience teaching Anatomy and Physiology, and remains active in academia. He resides in Florence, S.C.