

**THE INFLUENCE OF PHYSICAL ACTIVITY AND BMI ON BLOOD PRESSURE IN  
AFRICAN-AMERICAN WOMEN**

by

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Submitted to the Graduate Faculty of  
The Department of Health and Physical Activity in partial fulfillment  
of the requirements for the degree of  
Doctorate of Philosophy

University of Pittsburgh  
2011

UNIVERSITY OF PITTSBURGH

SCHOOL OF EDUCATION

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# THE INFLUENCE OF PHYSICAL ACTIVITY AND BMI ON BLOOD PRESSURE IN AFRICAN-AMERICAN WOMEN

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University of Pittsburgh, 2011

**Introduction:** African-American women are among those with the highest rates of obesity and hypertension, while also having low rates of physical activity (PA). While weight loss and PA have been implicated as lifestyle factors that can reduce blood pressure, the influence of these lifestyle factors on blood pressure in African-American women is not well studied, and the existing research has shown inconsistent findings.

**Purpose:** To examine the relationship between the change in measures of adiposity and resting systolic (SBP) and diastolic (DBP) blood pressure in overweight and obese non-hypertensive African-American women. In addition, this investigation will examine the influence of changes in PA and/or fitness on the relationship between the change in measures of adiposity and the change in resting SBP and DBP.

**Methods:** Data from 97 overweight and obese ( $31.4 \pm 4.0 \text{ kg/m}^2$ ), non-hypertensive African-American women who participated in one of 5 weight control interventions were analyzed for this study. The behavioral weight control interventions included dietary restriction and/or PA. Outcome measures included weight, body mass index (BMI), waist circumference, body composition, PA, and fitness. The hypotheses were tested using linear regression analysis. The mediation hypothesis was tested using linear regression analysis and separately adjusting for fitness and PA.

**Results:** There was a significant reduction in weight ( $5.0\pm 5.9$ ) systolic ( $4.4\pm 10.9$  mmHg), and diastolic blood pressure ( $2.8\pm 7.7$  mmHg). The change in SBP was significantly correlated with change in weight, BMI, waist circumference, and fitness, with the change in DBP significantly correlated with weight, BMI, waist circumference, PA and fitness. The relationship between measures of both weight and BMI and resting SBP were fully mediated by the change in either PA or fitness, with the relationship between change in waist circumference and change in SBP partially mediated by the change in either PA or fitness. The relationships between DBP and measures of adiposity were fully mediated by the change in either PA or fitness.

**Conclusion:** These findings highlight the potential importance of PA and fitness within the context of weight control for reducing resting blood pressure in overweight and obese African-American women.

## TABLE OF CONTENTS

<b>PREFACE.....</b>	<b>XIII</b>
<b>1.0 BACKGROUND, SIGNIFICANCE, AND SPECIFIC AIMS.....</b>	<b>1</b>
<b>1.1 BACKGROUND .....</b>	<b>1</b>
<b>1.2 SIGNIFICANCE.....</b>	<b>4</b>
<b>1.3 SPECIFIC AIMS .....</b>	<b>5</b>
<b>1.4 RESEARCH HYPOTHESES .....</b>	<b>6</b>
<b>2.0 REVIEW OF LITERATURE .....</b>	<b>8</b>
<b>2.1 DEFINING HYPERTENSION .....</b>	<b>8</b>
<b>2.2 HEALTH RISK ASSOCIATED WITH HYPERTENSION .....</b>	<b>9</b>
<b>2.3 PREVALENCE OF HYPERTENSION IN ADULTS .....</b>	<b>11</b>
<b>2.3.1 Influence of Gender on The Prevalence Of Hypertension.....</b>	<b>11</b>
<b>2.3.2 Influence Of Ethnicity On The Prevalence Of Hypertension.....</b>	<b>12</b>
<b>2.3.3 Influence of Age On The Prevalence Of Hypertension .....</b>	<b>14</b>
<b>2.4 LIFESTYLE INFLUENCES ON HYPERTENSION .....</b>	<b>15</b>
<b>2.4.1 Effects Of Sodium.....</b>	<b>16</b>
<b>2.4.2 Effects of Multi-Component Diet .....</b>	<b>18</b>
<b>2.4.3 Alcohol .....</b>	<b>20</b>
<b>2.4.4 Overweight And Obesity.....</b>	<b>25</b>

2.4.5	Weight Loss .....	26
2.4.6	Physical Activity .....	27
2.4.6.1	Physical Activity, Blood Pressure, Women.....	31
2.4.6.2	Physical Activity, Blood Pressure, African-American Women .....	32
2.4.7	Smoking.....	33
<b>3.0</b>	<b>METHODS .....</b>	<b>37</b>
<b>3.1</b>	<b>INTRODUCTION .....</b>	<b>37</b>
<b>3.2</b>	<b>SUMMARY OF RESEARCH APPROACH.....</b>	<b>37</b>
<b>3.3</b>	<b>SUBJECT RECRUITMENT AND SCREENING .....</b>	<b>38</b>
<b>3.4</b>	<b>DESIGN AND INTERVENTION OF EACH STUDY .....</b>	<b>41</b>
3.4.1	Study 1: Dose-Response of Exercise on Long-Term Weight Loss .....	41
3.4.2	Study 2: Mentor-Based Approach to Long-Term Weight Loss .....	43
3.4.3	Study 3: Enhancing Exercise Participation in Overweight Adults.....	45
3.4.4	Study 4: Evaluation of Alternative Exercise Treatments on Weight Loss in 49	
3.4.5	Study 5: Role of Exercise in the Prevention of Weight Gain.....	51
<b>3.5</b>	<b>COMMON OUTCOMES MEASURES .....</b>	<b>52</b>
3.5.1	Body Mass Index.....	53
3.5.2	Waist Circumference.....	53
3.5.3	Bioelectrical Impedance Analyzer (BIA).....	54
3.5.4	Blood Pressure .....	54
3.5.5	Cardiorespiratory Fitness.....	55
3.5.6	Physical Activity .....	55

3.6	STATISTICAL ANALYSIS .....	56
3.7	POWER ANALYSIS .....	57
4.0	RESULTS .....	58
4.1	DESCRIPTIVE CHARACTERISTICS OF SUBJECTS .....	58
4.2	INTERVENTION EFFECTS .....	59
4.3	ASSOCIATIONS BETWEEN CHANGE IN RESTING BLOOD PRESSURE FOR TOTAL SAMPLE (N=97) .....	63
4.3.1	Resting Systolic Blood Pressure .....	63
4.3.2	Resting Diastolic Blood Pressure.....	64
4.4	ASSOCIATIONS BETWEEN CHANGE IN RESTING BLOOD PRESSURE FOR SUBJECTS WITH A BASELINE RESTING SYSTOLIC BLOOD PRESSURE >120 MMHG (N=40) .....	65
4.4.1	Resting Systolic Blood Pressure .....	65
4.4.2	Resting Diastolic Blood Pressure.....	66
4.5	ASSOCIATIONS BETWEEN CHANGE IN RESTING BLOOD PRESSURE FOR SUBJECTS WITH A BASELINE RESTING DIASTOLIC BLOOD PRESSURE > 80 MMHG (N=35) .....	67
4.5.1	Resting Systolic Blood Pressure .....	67
4.5.2	Resting Diastolic Blood Pressure.....	69
5.0	DISCUSSION .....	72
5.1	CHANGE IN BLOOD PRESSURE IN RESPONSE TO A BEHAVIORAL WEIGHT LOSS INTERVENTION IN AFRICAN-AMERICAN WOMEN. ....	72

<b>5.2</b>	<b>ASSOCIATION BETWEEN CHANGE IN MEASURES OF ADIPOSITY AND CHANGE IN BLOOD PRESSURE .....</b>	<b>74</b>
<b>5.3</b>	<b>ASSOCIATION BETWEEN CHANGE IN RESTING BLOOD PRESSURE AND CHANGE IN PHYSICAL ACTIVITY.....</b>	<b>76</b>
<b>5.4</b>	<b>ASSOCIATION BETWEEN CHANGE IN RESTING BLOOD PRESSURE AND CHANGE IN FITNESS.....</b>	<b>78</b>
<b>5.5</b>	<b>MEDIATING EFFECT OF THE CHANGE IN PHYSICAL ACTIVITY OR FITNESS ON THE ASSOCIATION BETWEEN CHANGE IN MEASURES OF ADIPOSITY AND CHANGE IN RESTING BLOOD PRESSURE.....</b>	<b>80</b>
<b>5.6</b>	<b>EFFECTS OF EXERCISE ON POTENTIAL THAT INFLUENCES BLOOD PRESSURE.....</b>	<b>82</b>
<b>5.7</b>	<b>LIMITATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH.....</b>	<b>83</b>
<b>5.8</b>	<b>SUMMARY .....</b>	<b>85</b>
	<b>BIBLIOGRAPHY.....</b>	<b>86</b>

## LIST OF TABLES

Table 2.1: Blood pressure classifications.....	8
Table 2.3: Prevalence of hypertension by gender and ethnicity in adults >20 years of age.....	14
Table 2.4: Prevalence of hypertension by gender and age in adults > 20 years of age. ....	15
Table 3.1. Study Eligibility Requirements.....	40
Table 3.3. Dose-Response of Exercise on Long-Term Weight Loss Exercise Prescription for the Four Treatment Groups for 6 Months. ....	43
Table 3.4. Enhancing Exercise Participation in Overweight Adults Intervention.....	46
Table 3.5. Common Study Outcomes.....	53
Table 4.1: Descriptive characteristics of subjects.....	59
Table 4.2: Change in descriptive characteristics of subjects (N=97).....	60
Table 4.3: Change in descriptive characteristics of subjects with a resting systolic blood pressure >120 mmHg at baseline (N=40). ....	61
Table 4.4: Change in descriptive characteristics of subjects with a resting diastolic blood pressure >80 mmHg at baseline (N=35). ....	61
Table 4.5: Correlations between change in blood pressure and change in measures of body weight, body composition, physical activity and fitness (N=97). ....	62

Table 4.6: Correlations between change in blood pressure and change in measures of body weight, body composition, physical activity and fitness for subjects with a resting systolic blood pressure at baseline >120 mmHg (N=40). ..... 70

Table 4.7: Correlations between change in blood pressure and change in measures of body weight, body composition, physical activity and fitness for subjects with a resting diastolic blood pressure at baseline >80 mmHg (N=35). ..... 71

## LIST OF FIGURES

Figure 1.1: Theoretical Framework .....	5
Figure 2.1: Prevalence of hypertension by gender.....	12
Figure 2.2: Prevalence of hypertension by ethnicity .....	13

## **PREFACE**

I sincerely want to thank those individuals who have contributed to the completion of my dissertation at the University of Pittsburgh: Dr. John Jakicic, Dr. Robert Robertson, Dr. Elizabeth Nagle, and Dr. Bret Goodpaster. Additionally, I would like to thank my immediate family for all of your support and constant encouragement. I would like to dedicate this dissertation to the late Dr. Deborah J. Aaron without whom I would not have had the courage to begin this journey.

## **1.0 BACKGROUND, SIGNIFICANCE, AND SPECIFIC AIMS**

### **1.1 BACKGROUND**

Overweight and obesity is a major concern in the United States and other countries throughout the world. Based on a 2003 World Health Organization (WHO) report, over 1 billion adults were classified as overweight, with 300 million classified as obese [1]. Within the United States, fewer than one out of every three Americans are maintaining a healthy weight. Based on data from the 2007-2008 National Health and Nutrition Examination Survey (NHANES), 68.0 percent of adults in the United States are overweight (body mass index [BMI]  $\geq 25.0$  kg/m<sup>2</sup> and  $< 30.0$  kg/m<sup>2</sup>), 33.8 percent are categorized as grade 1 obesity (BMI  $\geq 30.0$  kg/m<sup>2</sup> and  $< 35.0$  kg/m<sup>2</sup>), 14.3 percent are categorized as grade 2 obesity (BMI  $> 35.0$  kg/m<sup>2</sup> and  $< 40.0$  kg/m<sup>2</sup>), and 5.7 percent are in the grade 3 obesity category (BMI  $\geq 40.0$  kg/m<sup>2</sup>) [2].

An important behavior that is linked to weight control is physical activity. It has been shown that physical activity can increase weight loss by an average of 3.0 kg by Donnelly, Blair, Jakicic, Manore & Rankin et al. [3] and may assist in the prevention of weight gain [4]. However, approximately 24 percent of adults in the United States are not physically active [5] with 33 percent of adults not meeting the minimum public health guideline of 150 minutes per week of moderate-intensity physical activity or 75 minutes per week of vigorous-intensity activity as recommended in the 2008 Physical Activity Guidelines for Americans [6].

The concern with high rates of overweight and obesity linked with low participation in physical activity is related to the increase in morbidity and mortality associated with these conditions. For example, excess body weight has been associated with increased risk of heart disease, cancer, diabetes, stroke, osteoarthritis, sleep apnea, and gall bladder disease. Moreover, overweight and obesity have been estimated to reduce the lifespan by 3 to 7 years [7] and has been estimated to cause an additional 111,909 deaths per year compared to individuals with a normal range of BMI [8].

Physical inactivity has also been linked to increased morbidity and mortality from numerous chronic diseases [9, 10]. The Harvard Alumni Study shows that when comparing men who performed less than 2000 kcal/week to those who performed more than 2000 kcal/week the relative risk of developing hypertension for the former group was 1.30 (95% CI: 1.09-1.55)[11]. The incidence of diabetes was reduced by 58% (95% CI: .48 -.66) in the lifestyle arm of the Diabetes Prevention Program where participants were asked to perform at least 150 minutes of physical activity per week when compared to the control arm (placebo) and the metformin arm which experienced a 31% reduction (95% CI: .17-.43)[12]. During the twenty year period between 1980 – 2000, a 2.3% reduction in physical inactivity contributed to 17,445 less deaths from coronary heart disease [13]. Consequently, the cost of physical inactivity in the United States is estimated at \$24.3 billion [14].

One of the key cardiovascular disease risk factors associated with excess body weight and physical inactivity is hypertension, and this can result in an increased risk for myocardial infarction [15, 16], heart failure [17, 18], stroke [19], kidney disease [20], metabolic syndrome [21], and cardiovascular disease and all-cause mortality [22, 23]. Hypertension affects more than 50 million individuals in the United States and as many as 1 billion individuals worldwide [24].

Hypertension is defined as having a systolic blood pressure  $\geq 140$  mmHg or a diastolic blood pressure of  $\geq 90$  mmHg or taking antihypertension medication [25]. The age-adjusted rate of hypertension is 30.9 percent, with the rates by gender being 30.3 percent for men and 31.0 percent for women [26]. When examined by age, there is evidence for increased prevalence with advancing age in more women with hypertension above 55 years of age than men [26]. Moreover, an estimated 69 million adults over the age of 20 years in the United States have pre-hypertension, with the majority of these individuals being women [27], and this is of concern because it is linked to a 1.5 to 2.0 fold increase in the risk of a major cardiovascular disease event in individuals under the age of 60 years [25].

The relationship between excess body weight and the prevalence of hypertension has been well documented [28, 29], yet there is still debate on the exact mechanism of this relationship [30]. Data from NHANES III supports the linear relationship between body weight and the prevalence of hypertension [31]. Moreover, Huang, Willett, Manson, Roster, and Stomper et al. [32] reported an 8 percent increase in risk of hypertension for each 1 kg/m<sup>2</sup> increase in BMI for individuals  $\geq 18$  years of age.

Physical activity is known to contribute to lowering BMI, and in addition to certain dietary restrictions, physical activity is recommended as a lifestyle modification for hypertension control. A recent synopsis of research presented by ACSM in a position stand revealed that dynamic exercise leads to a lower systolic and diastolic blood pressure in normotensive individuals but greater reductions were found in those who were hypertensive [33]. For example, a meta-analysis of randomized control trials showed physical activity led to an average decrease in SBP and DBP in hypertensives of 7.4 and 5.8 mm Hg, respectively. In addition, SBP

and DBP were lowered by 2.6 and 1.8 mm Hg in those with normal baseline blood pressure, both of which represent significant reductions [34].

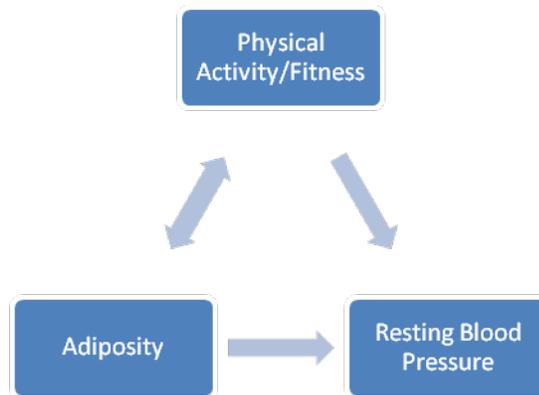
## 1.2 SIGNIFICANCE

African-American women and men possess the highest rates of hypertension when compared to other ethnic groups, with 41.5% of men and 44.4% of women diagnosed with hypertension [26]. Also, African-Americans have an earlier onset of hypertension, in addition to higher hypertension rates as children when compared to Caucasians [33, 35, 36]. This may contribute to the greater rates of non-fatal stroke (1.3), fatal stroke (1.8), death from heart disease (1.5), and end-stage kidney disease (4.2) experienced by African-Americans when compared to Caucasians [25]. Moreover, Fiscella and Holt [37] recently reported that an estimated 8,000 deaths could be prevented by reducing mean systolic blood pressure in the African-American population.

A factor that may contribute to the higher prevalence of hypertension in African-Americans is overweight and obesity. Current estimates indicate that 68.5% of African-American men and approximately 80% of African-American women are either overweight or obese [2]. Additionally, physical activity levels of African-Americans have been shown to be less than optimal, with almost 75% of African-Americans not participating in any vigorous activity [38]. Physical inactivity may be especially concerning for African-American women. This low level of physical activity may contribute to higher rates of obesity, as well as, higher rates of hypertension in African-American women. However, intervention studies of physical activity have yielded mixed results related to its effect on hypertension [39, 40]. Thus, it appears that additional research to understand the contribution of both obesity and physical activity on

blood pressure in African-American women is warranted. The theoretical framework that requires additional research is illustrated in Figure 1.

First paragraph.



**Figure 1.1: Theoretical Framework**

### **1.3 SPECIFIC AIMS**

The specific aims of this study are:

1. To examine the relationship between the change in adiposity and the change in resting blood pressure in African American women.
2. To examine the relationship between the change in physical activity and the change in resting blood pressure in African-American women.
3. To examine if the relationship between the change in adiposity and the change in resting blood pressure is mediated by physical activity in African-American women.  
To examine if the relationship between the change in adiposity and the change in resting blood pressure is mediated by fitness level in African-American women.

## 1.4 RESEARCH HYPOTHESES

1. It is hypothesized that:
  - a. There will be a significant relationship between the decrease in body mass index and the decrease in resting systolic blood pressure in African-American women.
  - b. There will be a significant relationship between the decrease in body mass index and the decrease in resting diastolic blood pressure in African-American women.
  - c. There will be a significant relationship between the decrease in waist circumference and the decrease in resting systolic blood pressure in African-American women.
  - d. There will be a significant relationship between the decrease in waist circumference and the decrease in resting diastolic blood pressure in African-American women.
2. It is hypothesized that:
  - a. There will be a significant relationship between the increase in physical activity and the decrease in resting systolic blood pressure in African-American women.
  - b. There will be a significant relationship between the increase in physical activity and the decrease in resting diastolic blood pressure in African-American women.
  - c. There will be a significant relationship between the increase in cardiorespiratory fitness and the decrease in resting systolic blood pressure in African-American women.
  - d. There will be a significant relationship between the increase in cardiorespiratory fitness and the decrease in resting diastolic blood pressure in African-American women.
3. It is hypothesized that:
  - a. Physical activity will mediate the relationship between the change in body mass index and the change in resting systolic blood pressure in African-American women.
  - b. Physical activity will mediate the relationship between the change in body mass index and the change in resting diastolic blood pressure in African-American women.
  - c. Physical activity will mediate the relationship between the change in waist circumference and the change in resting systolic blood pressure in African-American women.
  - d. Physical activity will mediate the relationship between the change in waist circumference and the change in resting diastolic blood pressure in African-American women.
4. It is hypothesized that:

- a. Cardiorespiratory fitness will mediate the relationship between the change in body mass index and the change in resting systolic blood pressure in African-American women.
- b. Cardiorespiratory fitness will mediate the relationship between the change in body mass index and the change in resting diastolic blood pressure in African-American women.
- c. Cardiorespiratory fitness will mediate the relationship between the change in waist circumference and the change in resting systolic blood pressure in African-American women.
- d. Cardiorespiratory fitness will mediate the relationship between the change in waist circumference and the change in resting diastolic blood pressure in African-American women.

## 2.0 REVIEW OF LITERATURE

### 2.1 DEFINING HYPERTENSION

Hypertension is defined based on resting levels of systolic (SBP) and/or diastolic (DBP) blood pressure. Current standards define hypertension as SBP  $\geq 140$  mmHg or DBP  $\geq 90$  mmHg or taking prescription antihypertensive medication [25]. Blood pressure classification for adults is described in the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC7) and these are illustrated in Table 2.1. [41].

**Table 2.1: Blood pressure classifications.**

<b>Classification</b>	<b>Resting Systolic Blood Pressure (mmHg)</b>		<b>Resting Diastolic Blood Pressure (mmHg)</b>
Normal	<120	and	<80
Prehypertension	120-139	or	80-89
Stage 1 hypertension	140-150	or	90-99
Stage 2 hypertension	$\geq 160$	or	$\geq 100$

## 2.2 HEALTH RISK ASSOCIATED WITH HYPERTENSION

There is a positive, graded and continuous relationship between blood pressure levels and death from ischemic heart disease (IHD) and stroke beginning at 115/75 mmHg in adults over 50 years of age [42]. Lewington et al. [42] studied one million adults with no previous vascular disease from 61 prospective studies in an effort to determine the relationship between blood pressure and vascular mortality. Results from this analysis show the risk of death from stroke is more than twofold beginning with usual SBP of 115 mm Hg in men and women over 50. In fact, when comparing men and women ages 40-49 to those 80-89 years old hazard ratios (95%CI) for SBP were twice as high for stroke (0.36), IHD (0.49), and other vascular mortality (0.43) [42].

The relative risk of CVD is higher in individuals who have borderline hypertension compared to those below normal [43]. Vasan et al. [43] examined three categories of middle-aged and elderly, non-hypertensive participants (n=6859) from the Framingham Heart Study in order to find the time to occurrence of various cardiovascular events such as stroke, myocardial infarction (MI), congestive heart failure (CHF), and death. The participants were divided among three normal blood pressure groups based on a base-line SBP/DBP as follows: optimal (<120/80 mm Hg), normal (120-129/80-84 mm Hg), and high-normal (130-39/85-89 mm Hg). During the follow-up, the following events were reported strokes (n=85), MI (n=190), CHF (n=50), and death (n=72). There was a significant difference in the risk of the first cardiovascular event in both men (M) (P=0.01) and women (W) (P<0.001) when comparing the optimal group to the high-normal group. During the 10 year follow-up period, the events were 1.6 and 2.5 times higher among the men and women, respectively, in the high-normal category. Moreover, a significant increase in risk [P for trend <0.001(M), <0.01(W)] of an event was reported for each blood pressure category.

Following this further, in a 19-year NHANES I follow-up study of 13,643 men and women, it was reported that the relative risk of congestive heart failure for those with hypertension is 1.50 (95% CI: 1.34 -1.68; P<.001)[18]. The study also estimates a population attributable risk (PAR) of 10.1% which represents the percentage of cases of congestive heart failure caused by hypertension within the general population [18].

High blood pressure is also a well-known cause of kidney disease. One-third of the new cases of end stage renal disease (ESRD) in 2007 was caused by hypertension [44]. In addition, there has been an 8% increase in ESRD's caused by hypertension since 2000 and half of the new patients who experience kidney failure caused by hypertension are African-Americans.

Unfortunately, the most recent (2006) death rate associated with hypertension was 17.8% [45]. Stratification of death rates by race and gender remain disproportionately higher for African-American men and women of 51.1% and 37.7%, respectively, but consistent with higher prevalence rates [45]. Overall, there has been an increase in the death rate of 19.5% over the ten-year period between 1996-2006[45]. The death rate translates into 56,561 deaths for U.S. men and women [45].

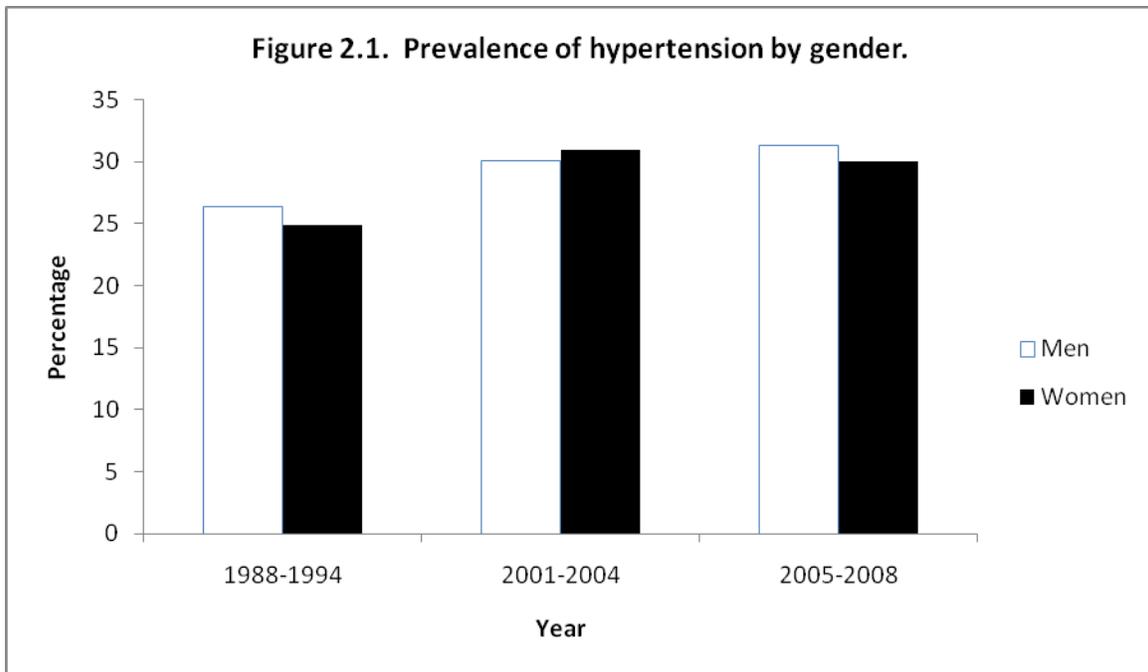
In conclusion, the growing concern to improve awareness, treatment, and control of hypertension is warranted because it is a known risk factor for myocardial infarction [15, 16], heart failure [17], stroke [19] kidney disease [20], and metabolic syndrome [21] (Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III), cardiovascular disease death and all-cause mortality [22, 23].

## **2.3 PREVALENCE OF HYPERTENSION IN ADULTS**

The age-adjusted hypertension rate in the United States for 2005-2008 is 30.9% [26]. Reported age-adjusted rates of hypertension for 2005-2008 in men and women 20 years and over is 31.6% and 29.8%, respectively [26]. Of significant public health importance is that [46] estimates that 1.56 billion people worldwide will have hypertension by 2025. These rates appear to vary by ethnicity, gender and age as described below.

### **2.3.1 Influence of Gender on The Prevalence Of Hypertension**

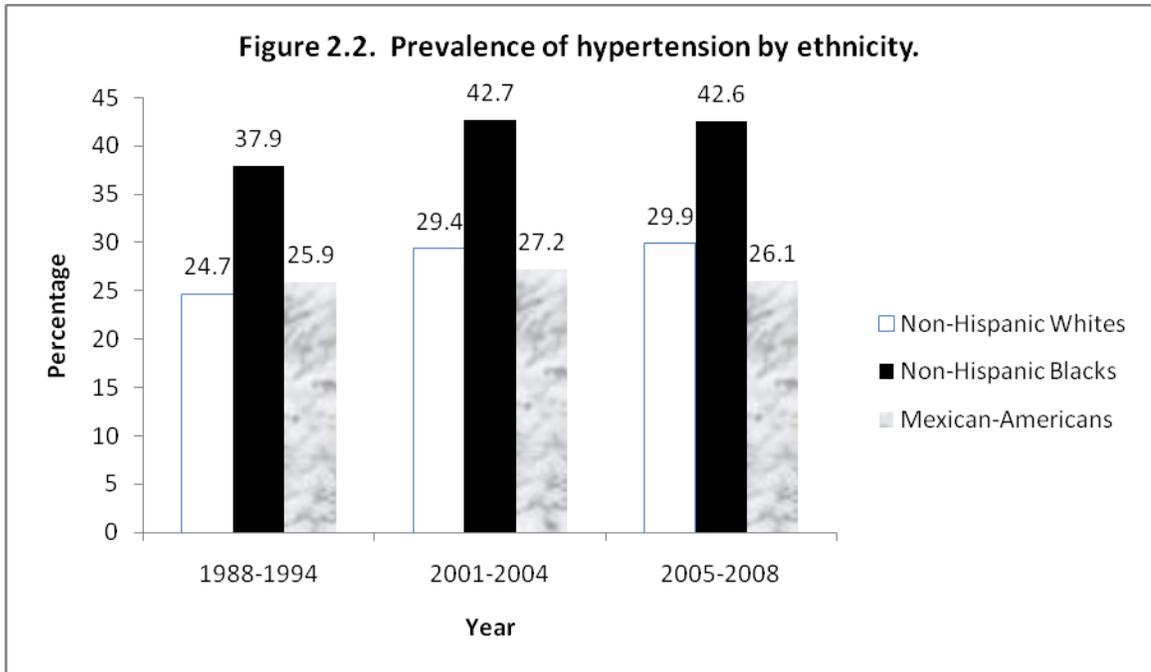
Prevalence data based on gender for adults  $\geq 20$  years of age are shown in Figure 2.1. Based on these data it appears that the prevalence rates are comparable between men and women. The most recent data from the 2005-08 National Health and Nutrition Examination Survey (NHANES) reflect similar prevalence levels of hypertension in men and women, with these rates being 31.3% and 30.0%, respectively. These prevalence rates appear to be relatively stable compared to the 2001-04 NHANES data, which reflected rates of 30.1% for men and 30.9% for women. However, this was an increase over the prevalence rates of 26.4% for men and 24.9% for women based on the 1988-1994 NHANES data.



**Figure 2.1: Prevalence of hypertension by gender**

### **2.3.2 Influence Of Ethnicity On The Prevalence Of Hypertension**

Data based on the 2005-08 NHANES survey grouped by ethnicity reveals the highest prevalence of hypertension to be among Non-Hispanic Blacks (42.6%) compared to Non-Hispanic Whites (29.9%) and Mexican-Americans (26.1%). The prevalence rates appear to have increased since the 1988-94 NHANES survey for both Non-Hispanic Blacks (37.9%) and Non-Hispanic Whites (24.7%), with little change observed for Mexican-Americans (25.9%). Prevalence data based on ethnicity are shown in Figure 2.2.



**Figure 2.2: Prevalence of hypertension by ethnicity**

Data are further presented by both gender and ethnicity in Table 2.3. These data indicate the highest prevalence of hypertension to be in Non-Hispanic Black women (43.9%); whereas, lower prevalence rates are observed in Non-Hispanic White (28.4%) and Mexican-American women 25%. A similar pattern is present for men, with Non-Hispanic Black men having the higher prevalence of hypertension (40.7%) compared to Non-Hispanic White (31.3%) and Mexican-American men (25.4%).

**Table 2.3: Prevalence of hypertension by gender and ethnicity in adults  $\geq 20$  years of age.**

Gender	Ethnicity	NHANES Survey Years		
		1988-1994	2001-2004	2005-2008
All	All	25.8%	30.7%	30.8%
	Non-Hispanic White	24.7%	29.3%	29.9%
	Non-Hispanic Black	37.9%	42.7%	42.6%
	Mexican-American	25.9%	27.2%	26.1%
Men	All	26.4%	30.1%	31.3%
	Non-Hispanic White	25.6%	29.3%	31.3%
	Non-Hispanic Black	37.4%	40.9%	40.7%
	Mexican-American	26.1%	25.5%	25.4%
Women	All	24.9%	30.9%	30.0%
	Non-Hispanic White	23.5%	29.0%	28.4%
	Non-Hispanic Black	38.1%	44.0%	43.9%
	Mexican-American	25.2%	28.7%	25.0%

### **2.3.3 Influence of Age On The Prevalence Of Hypertension**

Cross-sectional data indicates that the prevalence of hypertension increases as age increases for adults in the United States, and this pattern appears to be similar between men and women. These data are presented in Table 2.4. Moreover, all age groups experienced an increase in the prevalence of hypertension between the 1988-1994 NHANES survey and the 2005-2008 survey.

**Table 2.4: Prevalence of hypertension by gender and age in adults  $\geq 20$  years of age.**

Gender	Age (years)	NHANES Survey Years		
		1988-1994	2001-2004	2005-2008
All	20+ (age-adjusted)	25.8%	30.7%	30.8%
	20 to 44	8.7%	10.0%	11.1%
	45 to 64	33.5%	41.3%	40.6%
	65+ (age-adjusted)	61.8%	71.8%	70.6%
	65 to 74	55.4%	67.8%	66.5%
	75+ (age-adjusted)	68.8%	76.3%	75.0%
Men	20+ (age-adjusted)	26.4%	30.1%	31.3%
	20 to 44	10.9%	12.3%	14.1%
	45 to 64	34.2%	39.9%	40.2%
	65+ (age-adjusted)	57.3%	64.3%	65.5%
	65 to 74	54.4%	61.7%	64.0%
	75+ (age-adjusted)	60.4%	67.1%	67.2%
Women	20+ (age-adjusted)	24.9%	30.9%	30.0%
	20 to 44	6.5%	7.7%	7.9%
	45 to 64	32.8%	42.6%	41.1%
	65+ (age-adjusted)	64.5%	77.3%	74.1%
	65 to 74	56.2%	72.9%	68.4%
	75+ (age-adjusted)	73.6%	82.0%	80.0%

## 2.4 LIFESTYLE INFLUENCES ON HYPERTENSION

There are numerous lifestyle factors that are considered to be modifiable causes of hypertension. These lifestyle factors include higher levels of alcohol consumption[47], higher levels of sodium consumption [48], and lower consumption of fruits and vegetables. Also, the presence of overweight or obesity [49] and low levels of physical activity [50] have been shown to contribute to increased blood pressure and the development of hypertension.

### 2.4.1 Effects Of Sodium

Sodium intake has been associated with higher levels of blood pressure in animals and in humans. A study of baboons was performed by [51] to evaluate the effect of high salt intake on blood pressure. Three groups of baboons were observed beginning in the following age groups: birth, sexual maturation (1.5 - 2.5 yrs old), and adults (4 - 7 yrs old). Blood pressure was increased significantly ( $P < 0.01$ ) among all three groups after one year. The animals who were taken off the high salt regimen due to poor health after 1.5 years saw a return of normal blood pressure reading. Similar results were reported in blood pressure of chimpanzees by [52] who were fed added salt and other animals research studies of mice [53], pigs [54], rats [55] and rabbits [56].

The Intersalt study [57] is the most notable cross-sectional study aimed at assessing the relationship between dietary sodium and blood pressure within and among multiple populations. In the study of 52 populations from 32 countries, 10,079 individuals between 20 – 59 years old were analyzed using a standardized protocol. Each of the 52 centers was charged with recruiting 8 groups of 25 men and women within four age ranges (20 – 59 years old) or 200 participants. Sodium intake was measured by the amount of sodium excreted in each participants' urine within a 24 hour period. After adjustments for sex and age, within center results reflect a positive association between both SBP and DBP with age and sodium excretion [57]. However, significance was only reached in 15 centers for SBP ( $p < 0.05$ ) and 4 for DBP ( $p < 0.001$ ) [57]. There were four of the study populations whereby individuals with low sodium excretion values subsequently had low blood pressure. In fact, only a negligible increase in BP and sometimes a decrease in BP was found as the populations grew older. Consequently, these populations were omitted from analyses as outliers. Only when they were included did analyses across the 52

centers show a relationship between the two variables. Results differed from the hypothesis that both SBP and DBP would be positively related to sodium excretion in each age and gender group. There was a significant negative relationship in the 20 -29 year old group.

A very similar study was conducted using world populations; however, it did not include Intersalt data [58]. The blood pressure of 47,000 people was analyzed based on a difference in sodium intake of 100 mmol/24-h. Significant associations were reported in all six age groups (15-19, 20-29, 30-39, 40-49, 50-59, 60-69 years old). Differences reported for SBP in the 60 year olds was 10.3 mm Hg and half that (5 mm Hg) for the 15 year olds [58]. Based on their model, Law et al. [58] shows how greater reductions in BP occur as you age based on salt intake.

Several meta-analyses of RCT's have been performed on this topic which provide conflicting results. More recently, Hooper et al. [59] reviewed randomized controlled trials of individuals with uncontrolled hypertension, controlled hypertension, and without hypertension. Although there was a small but significant reduction in SBP of 1.1 mm Hg (95% CI: 1.8 to 0.4 mm Hg) from studies with a 13 to 60 month follow-up, no relationship was found between blood pressure and decreased sodium intake [59].

Similarly, others reported on the lack of a relationship between sodium restriction and blood pressure [48], [60], [61]. For example, Grobbee and Hoffman [61] reviewed 13 randomized studies (mean age 38.5 years old) of low sodium diets and no association was found, despite the fact that the average blood pressure was lowered by 3.6/2.0 (SBP/DBP). He and MacGregor [62] demonstrated that sodium reduction leads to lower blood pressure in a meta-analysis of 20 randomised trials. The studies included were at least four weeks in length (median = 4 weeks normo-tensives; 5 weeks hypertensives). Salt was reduced in 802 middle-

aged individuals, with hypertension from an average of 162 mmol/d to 87 mmol/day. As a result, a significant decrease was reported using the random effects model. SBP and DBP dropped -5.27 mmHg (95% CI:-6.69 to -3.85) and -2.76 mmHg (95% CI: -3.55 to -1.97), respectively. In fact, the author posits a 100 mmol/d decrease in sodium is associated with a 7.2 mmHg (95% CI: 5.6 to 8.8) SBP and 3.8 mmHg (95%CI: 2.8 to 4.7) DBP in hypertensives. In the same way, normo-tensives (n=2220), median age 47, who were analyzed separately, lowered their daily intake from an average of 154 mmol/d to 82 mmol/d. The associated SBP reduction was -2.03 mmHg (95%CI: -2.56 to -1.50) and -0.99 mmHg (-1.40 to -0.57) for DBP [62].

In conclusion, the evidence for the reduction of sodium intake remains unresolved. Some evidence suggests that reductions in sodium intake alone can produce decreases in blood pressure in both normo- and hypertensives [61-63]. More often the greatest response to sodium reduction is found in hypertensives and older participants [59, 61, 63]. SBP was shown to decrease by between 2 - 8 mm Hg when daily intake of sodium did not exceed 100 mmol threshold [48, 64]. Also, combinations of the DASH diet and decreased amounts of sodium have also produced decreases in SBP on average by 11.5 mm Hg [65]. Finally, a recent consensus report from the Institute of Medicine (IOM) [66] suggests that 100,000 lives could be saved from a population-wide reduction in sodium intake. The IOM also recommends a reduction of RDA of sodium from 2,300 mg to 1,500 mg for adults and less for adults over 50 [66].

#### **2.4.2 Effects of Multi-Component Diet**

A healthy diet is recommended for individuals who are hypertensive in order gain BP control [67]. Diets similar in composition to the one used in the Dietary Approaches to Stop

Hypertension (DASH) protocol which are high in fruits, vegetables, legumes, whole grains, and lean meats (poultry and fish) have led to decreases in SBP of approximately 6-14 mmHg [65, 68].

In the study by Sacks and colleagues [65] of sodium intake, diet, and hypertension, 412 participants were randomized to a control diet (typical American diet) or a DASH diet with additional sodium restriction of 150 mmol (high), 100 mmol (intermediate), and 50 mmol (low) in a parallel crossover design. The participants maintained assigned diet at prescribed level of sodium for 30 days. Primary (SBP) and secondary (DBP) outcome measures were taken at the end of each 30 day period. Significant decreases were reported in mean blood pressure levels for both diet types. For example, SBP decrease for reduction in sodium from the high to intermediate level was (-2.1 mm Hg; 95%: -3.4 to -.08;  $P < 0.001$ ) for the control diet and (-1.3 mm Hg; 95%: -2.6 to 0.0;  $P < 0.05$ ) for the DASH diet. Not only was the decrease in blood pressure significant for the first step down, but also there was also a significant reduction when sodium was stepped down a second time below current recommendation of 100 mmol (intermediate) to 50 mmol (low). SBP was reduced by (-4.6 mm Hg; 95%: -5.9 to -3.2;  $P < 0.001$ ) and DBP by (-2.4 mm Hg; 95%: -3.3 to -1.5;  $P < 0.001$ ) for control diet and SBP (-1.7 mm Hg; 95%: -3.0 to -0.4;  $P < 0.01$ ) and DBP (-1.0 mm Hg; 95%: -1.9 to -0.1;  $P < 0.01$ ) for DASH diet. The results of combining DASH and low sodium level offers the greatest reduction in SBP (-8.9 mm Hg; 95%: -6.7 to -11.1;  $P < 0.001$ ) when comparing the high-sodium control diet and the low-sodium DASH diet versus DASH alone (-3.0 mm Hg) or low sodium alone (-6.7 mm Hg).

All of the aforementioned reductions in blood pressure occurred while weight remained constant. Sodium levels had an effect on both participants who were hypertensive and those who were not. For instance, when comparing the high sodium control diet to low sodium DASH

diet, SBP dropped -11.5 and -7.1 mm Hg in hypertensives and non-hypertensives, respectively. An analysis of subgroups by gender was performed and women had significantly larger SBP reductions of -10.5 mm Hg ( $P<0.001$ ) compared to SBP reductions in men of -6.8 mm Hg.

Sacks et al. [65] also reported in subgroup analyses by race that African American hypertensives and non-hypertensives were able to reduce SBP by -12.6 mm Hg and -7.2 mm Hg respectively in the low sodium DASH combination compared to those African Americans in the high sodium control diet ( $P<0.001$ ). Also, a significant reduction was found ( $P=0.007$ ) in African Americans who were on the control diet when compared to all other races. A different study using an African-American subgroup participating in DASH diet research exhibited a significantly greater reduction in DBP (primary outcome) of -6.8 mm Hg than that found in Whites (-3.0 mm Hg) [68]. Similar results have been reported in African-Americans [69] and it is suggested that the greater effect from salt is found in that cohort due to salt sensitivity.

### **2.4.3 Alcohol**

Alcohol consumption is modifiable correlate of hypertension. It is recommended that individuals limit consumption of alcohol to 2 drinks per day for men and 1 drink per day for women [41] to manage or prevent hypertension. Daily consumption which exceeds the recommendation of 1 oz of ethanol (30 mL) [i.e. 10 oz. wine (300 mL), 2 oz. 100-proof whiskey (60 mL), 24 oz beer (720 mL)] in men and up to 0.5 oz. of ethanol for women [70] is associated with higher blood pressures in people with and without hypertension [71] and irrespective of the type of alcoholic beverage such as red wine, beer, or liquor [72-74].

This can be seen in the results of a Kaiser-Permanente study which examined and questioned over 66,000 people in order corroborate the relationship between blood pressure and alcohol use. In general, an increase in blood pressure was seen with daily alcohol intake. Differences in blood pressure patterns were found in race and sex subsets. For example, significant increases were apparent in SBP ( $P<0.001$ ) in White men and DBP ( $P<0.001$ ) in White men and women beginning at 1-2 drinks per day compared to nondrinkers [75]. This pattern reached a threshold and SBP and DBP decreased in women ( $n=26$ ) who consumed nine or more alcoholic beverages each day .

African-American women who consumed 1-2 and 6-8 alcoholic beverages per day had significantly higher DBP when compared to nondrinkers, ( $P<0.001$ , 0.01, respectively) [76]. Furthermore, no significant positive relationship to SBP was found, and a negative association was apparent in those consuming 6-8 beverages per day compared to non-drinkers [76]. Finally, in black men the relationship was significant in SBP/DBP at every level of consumption; however, a plateau was reached at 3-5 beverages/day [76]. Other investigators have also reported a dose-response association [75, 77, 78]. The relationship between alcohol and blood pressure is found even when controlling for age [79]; however, a stronger relationship is present in older individuals [77, 78].

Similarly, in a meta-analysis of randomized controlled trials on this topic, a dose-response relationship was observed between decreasing alcohol consumption and decreasing blood pressures in individuals with a baseline alcohol intake of 3 to 6 beverages per day [80]. The studies reviewed in this meta-analysis primarily consisted of male participants. Fifteen randomized trials of hypertensives ( $n=7$ ) and normotensives ( $n=6$ ) were reviewed. Significant mean reductions in both SBP -3.31 (95% CI:-2.52 to -4.10 mm Hg;  $P<0.0001$ ) and DBP-2.04

(95% CI:-1.49 to -2.58 mm Hg;  $P < 0.0001$ ) were reported as a result of the mean self-reported decrease in daily alcohol consumption of 67% from baseline amounts [80].

Another study of alcohol withdrawal was conducted in heavy drinkers ( $>200$  g/day) with hypertension. Soardo and colleagues [81] compared two groups of hypertensive alcoholics over the course of 30 days to determine the change in blood pressure resulting from the complete cessation of alcohol intake. The mean blood pressure of the hypertensives who withdrew from alcohol was significantly lower compared to the hypertensives who did not change their consumption ( $131 \pm 3/81 \pm 2$  mmHg vs.  $165 \pm 4/94 \pm 3$  mmHg;  $P < 0.01$ ) [81]. In fact, normal BP levels were apparent in some patients as early as the second week. Normal BP levels had been restored in all but one patient by the end of the study [81]. Additionally, Soardo et al. [81] reports a positive significant correlation between BP at baseline and the size of the BP change ( $r = 0.60$ ;  $P < 0.02$ ). A similar linear association between the amount of alcohol consumed and increasing blood pressure was reported by others [72, 82, 83].

Recently, a prospective study of men ( $n=13,455$ ) and women ( $n=28,848$ ) was performed to determine hypertension risk based on alcohol consumption. There were 6012 and 8680 incident cases of hypertension in men and women over a median follow-up period of 9.8 and 17 years, respectively [84]. The relative risk of hypertension in men (1.12[1.01 to 1.23]) is apparent at 1 – 3 alcoholic beverages per month; however, a consistent linear pattern persists with consumption which exceeds 5 per week ( $P$  for trend  $< 0.0001$ ) [84].

In contrast, there is research that supports the assertion that low to moderate amounts of alcohol may provide a protective effect [73, 84]; however, the data are not conclusive. For example, [72] found that low-to-moderate consumption of alcohol ( $\leq 3$  drinks per day) was

protective against the development of hypertension in Non-Hispanic Black women, Non-Hispanic White women and Non-Hispanic White men; however, this level of alcohol consumption was a significant risk factor for hypertension in African-American men (OR 95% CI: 1.46(0.96 to 2.20)).

Sesso et al. [84], reported no benefit to blood pressure in men who consumed light-to moderate (1 drink/ month - 1 drink/day) amounts of alcohol. For women, a J-shaped association was observed with a relative risk of 0.79 (95% CI: 0.71 to 0.89) hypertension with consumption of 5 to 6 drinks per week compared to lower levels of consumption [84]. Yet another investigator reports a U-shaped relationship in women over 35 years old. A relationship which indicates that nondrinkers have elevated BP's which parallel those who consume more than 30 mL per day [78].

Thadani and colleagues [73] examined hypertension risk in women (n=70,891) between 25 and 42 years old and reported that drinking .26 to .50 drinks per day resulted in a 14% lower risk of developing hypertension than those who are nondrinkers, but the risk increased by 44% in women who consumed 1.5 or more drinks per day. Nanchahal and colleagues [85] found that the odds ratio of hypertension was 1.68 (95% CI: 1.14-2.46) among women (n=14,077) drinking between 15-21 units/week versus non-drinkers(< 1 units/week). Similarly, a study of 58,218 nurses (women), compared nondrinkers not only to those who consumed 2-3 drinks per day (20 – 34 g), but also those consuming > 3 drinks per day and the risk of hypertension increased significantly RR=1.4 and 1.9(95%CI), respectively [86]. In women, no risk was associated with consumption of less than 20g/day. In the CARDIA study, light (<4/week [W],7/week[M]) and moderate (4-7/week[W], 7-14[M]) consumption is associated with a lower risk of hypertension

in European-American women only. No association was found in European men and African-American men and women at that level of consumption compared to never drinkers [87].

In a cross-sectional examination of African-Americans, Strogatz et al. [82] found that those who consume 7 drinks or more per week had a blood pressure 6.8 mm Hg ( $P < 0.001$ ) higher than that of the nondrinkers. In the same way, Curtis and colleagues [88] found a significant relationship between changes in drinking status (nondrinkers to drinkers) and systolic blood pressure of African-Americans over a five year period. SBP and DBP increased by 6.2 mm Hg (95% CI: 1.3 to 11.1) and 3.3 mm Hg (95% CI: -0.6 to 7.3), respectively. Additionally, those who initiated use of alcohol were 1.6 times more likely to become hypertensive than those who abstained RR=1.6 (95% CI: 0.6 to 4.5) [88]. Alternatively, no association was found between baseline consumption of alcohol and incident hypertension over a twenty year longitudinal study in a cohort of young African-Americans in the CARDIA study [87].

In conclusion, consistent consumption of alcohol ( $\geq 30$  ml) [76, 78] is a correlate of blood pressure and potential development of hypertension [72, 89]. The relationship between alcohol and blood pressure is independent of type of alcohol consumed [76, 83]. The benefits of alcohol consumption are not definitive and tend to vary by ethnicity, gender, and age [90]. The research available shows that light-to-moderate consumption may provide some benefits for women consuming up to .50 drinks per day or less than 20g/day and heavy drinking in men and women is a correlate of elevated blood pressure and hypertension [87].

#### 2.4.4 Overweight And Obesity

Overweight and obesity are correlates of hypertension. Stamler et al. [28] demonstrated that elevated blood pressure in overweight people was double that of normal weight individuals and triple that of underweight individuals between 20 and 39 years old. The relationship held true per each age-sex-race group. The study also reported a higher frequency of hypertension when using higher cutoff points (i.e.  $>95$ ;  $>105$  DBP) to compare overweight with normal weight individuals. Similar results were found in obese populations [31, 91, 92]. Systolic and diastolic blood pressures are shown to increase at every level of BMI, including BMI levels  $\geq 30$  in the National Health and Nutrition Examination Survey III 1988-1994 [91]. SBP in men and women was approximately 9 mm Hg and 11 mm Hg higher respectively, in those with BMI's  $\geq 30$  compared to those  $<25$ . The same was true of DBP, a difference of approximately 7 mm Hg and 6 mm Hg for men and women in the highest versus the lowest BMI categories.

Among African-American men and women a trend is shown to exist between increasing BMI's and blood pressures [91]. However, there is research which indicates that hypertension rates among African-Americans are not driven by overweight/obesity [28, 91, 93-95]. For example, there is a greater increase in the risk of HTN in White women (RR=2.6) than in African-American women (RR=1.5) who are overweight [96]. Taylor et al. [95] also reports that when comparing participants from the Framingham Heart Study (FHS) to the Jackson Heart Study (JHS) an increase in BMI was tantamount to an increase in BP; however, OR at each level of BMI (25,  $\geq 30$ ,  $\geq 35$ ) was significantly (P=0.014, 0.007, and  $<0.001$  respectively) lower in the JHS.

## 2.4.5 Weight Loss

It has been demonstrated in weight loss studies that SBP and DBP are lowered with a 4-8% weight loss [97-100]. The results of a review of studies with a two-year minimum follow-up period indicated that DBP and SBP may be reduced by 4.6 and 6.0 mm Hg respectively with body weight loss of 10-kg [101].

Stevens et al. [49] compared three weight loss groups (successful maintenance, relapse, and no loss) based on the amount of weight lost at months 6 and 36. Successful participants lost at least 4.5 kg at month 6 and maintained it at month 36; relapse participants lost at least 4.5 kg at month 6 and less than 2.5 kg at month 36; and no loss participants have weight loss of less than 2.5 kg at both time points. The successful maintenance group had the most considerable weight loss and decrease in BP. SBP and DBP decreased from baseline by 5.0 mm Hg and 7.0 mm Hg resulting from a mean weight loss of -8.8 kg [49]. Thus, a significantly lower relative risk was reported in both the relapse participants 0.75 (CI, 0.53 to 1.04) and the successful maintenance participants 0.35 (CI, 0.20 to 0.59) compared to controls. Modest weight loss (i.e. 10 lbs) has been shown to decrease blood pressure levels [102], and in the event of weight regain, hypertension risk is lower [103] and level [104, 105] remains lower in weight loss group.

A meta-analysis of randomized controlled trials on weight loss and blood pressure which included 4874 subjects with a mean BMI of 30.7 kg/m<sup>2</sup> estimates blood pressure is reduced by -1.05 mm Hg (95% CI, -1.43 to -0.66) SBP and -0.92 mm Hg (95% CI, -1.28 to -0.55) DBP for each kilogram of weight loss [106]. Overall, significant SBP and DBP reductions were found of -4.44 mm Hg (95% CI, -5.93 to -2.95) and -3.57 mm Hg (95% CI, -4.88 to -2.25) from an average decrease in weight of -5.1 kg caused by physical activity, calorie restriction, or both

[106]. Similar results (from weight loss) in blood pressure from physical activity [107] or diet [108].

On the contrary, no significant differences in blood pressure were found between control and intervention subjects who lost 4.1 kg [109]. In addition, Hagberg et al. [110] examined 61 studies of exercise induced weight loss and BP and a non-significant correlation of  $r = 0.11, 0.07$  in SBP and DBP, respectively. To that end, a Cochrane review [62] on weight loss for HTN control failed to confirm that weight loss in and of itself causes lower BP with 95% certainty.

#### **2.4.6 Physical Activity**

Physical activity has been a proven strategy for lowering resting blood pressure in normotensive and hypertensive adults. Physical activity can lower blood pressure independently of weight loss [50]. Many of the leading health organizations [41, 111] support the use of regular physical activity as a non-pharmacological strategy for reducing blood pressure, in addition to achieving and improving blood pressure control. The results of the research in this area have been reported primarily for Whites [50, 112, 113] and males [11, 112] despite the fact that African-American cardiovascular mortality rates [114] and hypertension rates are among the highest in the world [13].

A positive relationship exists between hypertension and the quantity of physical activity, as well as, the level of fitness in white men. Evidence of this was reported by the Harvard Alumni Study investigators in a comparison of activity levels by caloric expenditure. Men who completed more than 2000 kilocalories (kcal) per week of activity were 30% less likely to become hypertensive than those men who had a level of activity below 2000 kcal per week

[115]. Similar results were reported in Atherosclerosis Risk in Communities Study (ARIC) [116] where the most active men were 34% less likely to become hypertensive (OR=.66, 95% CI=0.47-0.94; P for quartile trend = 0.01). A separate analysis of 14,988 Harvard alumni shows a relationship between vigorous activity and hypertension risk. Men who engaged in vigorous activity were 35% less likely to become hypertensive than men who did not [115]. In fact, an inverse relationship was found among overweight-for-height men and vigorous activity.

In the Tecumseh Community Health Study [117] lower blood pressure was associated with high levels of activity. Six physical activity indices of daily energy expenditure were examined and a significant difference ( $P < .05$ ) in mean (DBP) was found across all age groups of men when the highest level of occupational energy expenditure was compared to the lowest level of occupational energy expenditure. A significant difference was also seen in the 45-54 year old age group in SBP and DBP when occupational activity was combined with leisure-time activity.

More recently, prospective studies show a protective effect of physical activity in men and women. In a Finnish study [118] of 6,787 men and women over 35 years old an association between leisure-time physical activity and hypertension was identified in men only. However, age-adjusted hypertension rates were lowest among the most active group of men and women. The groups were stratified into three levels of energy expenditure per week ( $< 1100$ , 1101-1900, 1900 kcals per week for men and  $< 900$ , 901-1500,  $> 1500$  kcals per week for women). Also, vigorous activity was defined as at least one bout of activity at  $\geq 6$  METS. The relative risk for the least active men was significant for energy expenditure (RR=1.73; CI: 1.13-2.65) and amount of vigorous activity (RR=1.56, CI: 1.07-2.28), conversely no association was found in women for either of the two measures over the ten year follow-up period. Blair, Goodyear, Gibbons and

Cooper [119], and others [120, 121] show that baseline levels of physical fitness are also correlates of future hypertension. For example, hypertension risk for men and women with low levels of fitness was 1.52 times greater than those who were more fit [119].

Physical activity has also been shown to lower blood pressure in individuals who are pre-hypertensive [50, 112, 122] in addition to those with hypertension [123-126]. The amount of the reduction in blood pressure varies by study; for example, reductions as high as 10.5mmHg (SBP) and 8.6mmHg (DBP)[113] to -4.23 mm Hg (SBP) and -2.91 mm Hg (DBP) [includes pre-hypertensive individuals] [50]. Greater reductions are reported in individuals with the more severe elevations of blood pressure [50, 123, 127].

Randomized controlled trials have shown that aerobic exercise affects resting blood pressure in hypertensive's and normotensives. Many of these interventions include subjects who are normo-tensive or pre-hypertensive, those individuals having blood pressure above optimal, but below clinical hypertension levels. In the most recent Position Statement (2004) from the American College of Sports Medicine, evidence category "A" was assigned to the evidence supporting the fact that resting blood pressure is reduced in normo-tensive and hypertensive individuals who perform dynamic aerobic training. In the assessment of numerous meta-analyses, the participants were between 18 and 79 years old (M~45) and were primarily men. The length and frequency of training was between 4 weeks and one year (M~16wks) and once per week to every day, respectively. The median time of training was ~40 minutes. Various training intensities were examined between 30% and 90% of VO<sub>2</sub> max. Multiple modalities were used such as cycling, running, jogging, and walking. Hence, overwhelming data support a consistent pattern among the studies that indicated BP decreases as a result of exercise training[33].

It is common in most reviews of randomized controlled trials on this topic that the age range, gender, ethnicity of study group, as well as the length, frequency, and intensity of protocol vary greatly. Most of the studies included randomization, an aerobic intervention, a control group (no exercise), and although other variables are measured resting blood pressure is the primary outcome. For instance, Hagberg and Brown [113] reviewed 53 groups of people from 47 studies who were hypertensive based on an elevated systolic or diastolic blood pressure reading. The authors reported an exercise induced reduction of 10.5 mmHg and 8.6 mmHg, systolic and diastolic, respectively. More than half of the studies contained men and women. The training intensities varied from 40 – 70%  $\text{VO}_2\text{max}$ ; in particular, a 40% greater reduction in systolic blood pressure was detected in subjects who trained at intensities below 70%  $\text{VO}_2\text{ max}$ . While 70% of the study groups were able to reduce systolic blood pressure independent of length of training protocol, it was concluded that larger reductions are achievable with longer training programs(>10 weeks). Subjects who were between 41-60 years of age had a weighted average reduction of 12.4 mmHg (SBP) and 8.5 mmHg (DBP) which was significantly greater than cohorts who were both younger and older.

Hagberg and colleagues [110] reported very similar results in a review of 1284 subjects in 74 groups with hypertension averaging 153 mm Hg (SBP). A 76% reduction in systolic blood pressure was attained in 56 groups; however, the average 10.6 mmHg reduction which was significant did not curtail systolic blood pressure to within the normal range. Yet, 81% of the groups were successful with reaching normal levels (less than 90) in diastolic blood pressure.

Some, but not all studies find that physical activity leads to a reduction in blood pressure. For example, Hagberg and Brown [113] reported a negative response (no significant decrease in blood pressure) in 25% of the groups studied in both of the aforementioned reviews. In fact, a

significant increase in diastolic blood pressure was evident in one of the groups after 12 months of endurance training [128]. Cononie and colleagues [129] reported an average decrease in systolic blood pressure of 8 mmHg and 9 mmHg in diastolic blood pressure in an older hypertensive population of men and women. The baseline or initial stage of resting blood pressure may determine the extent to which it will be reduced particularly if blood pressure levels are elevated beyond Stage 1 [123, 130]. On the other hand, lack of well-controlled trials has been identified as a cause of larger reductions in resting blood pressure. Still, it is thought that pooling results from randomized controlled trials is common in meta-analyses would allow for accurate statistical analysis of the effect of aerobic exercise on blood pressure [50].

#### **2.4.6.1 Physical Activity, Blood Pressure, Women**

There is a paucity of research on hypertension and aerobic exercise in women. The research available has provided some conflicting results in hypertension outcomes in women. Kelley [122] performed a meta-analysis of resting blood pressure and aerobic exercise in women. Ten studies were accepted for inclusion in the analysis which was comprised of 504 exercise and 228 control subjects. The average length of training protocols was  $31 \pm 16.8$  weeks, frequency  $4 \pm 1$  days/week, and intensity  $63 \pm 11.9\%$   $\text{VO}_2\text{max}$ , and duration  $39 \pm 12.9$  min/session. The age of the subjects spanned the adult lifespan up to approximately 70 years old  $53 \pm 7.3$ ; controls,  $56 \pm 7.4$ . Baseline blood pressure was within the normal range  $119 \pm 10.1$ [SBP]/  $73 \pm 5.6$ [DBP] in exercise group and  $123 \pm 11.6$ [SBP]/  $75 \pm 6.7$ [DBP] and control group. A nominal decrease in resting blood pressure was reported of 2% ( $-2 \pm -2.6$  mm Hg [SBP]) and 1% ( $-1 \pm 1.9$  mm Hg[DBP]) which does not represent a significant difference between the groups.

Duncan et al. [131] reported non-significant changes in SBP ( $-3$  mm Hg) in women occurred in the low intensity walking group (56% MHR) over a 24 week trial when compared to

controls and two additional groups walking at 67% and 86 % (MHR); however, baseline pressures were also within the normo-tensive range. Haapanen and colleagues [118] found no association in middle-aged women (35-63 years old) between hypertension risk or intensity level and amount of leisure-time activity. Furthermore, a 7.5 year prospective analysis of runners by Williams [132] revealed that baseline fitness level (based on running speed) was a significant predictor of incident hypertension ( $P < 0.001$ ) in women; but, there was no association between kilometers run and hypertension.

Conversely, in an intervention for women designed to test effectiveness of ACSM-CDC recommendations for moderate-intensity exercise found that after 12 weeks SBP was significantly reduced ( $P < 0.05$ ) from  $142 \pm 3$  mm Hg to  $136 \pm 2$  mm Hg. An additional reduction in SBP was realized at the conclusion of the 24 week study of 5 mm Hg ( $P < 0.005$ ) in this cohort of postmenopausal women [133].

#### **2.4.6.2 Physical Activity, Blood Pressure, African-American Women**

Research which focuses primarily on hypertension, physical activity, and African-American women is limited. Kelly, et al. [123] completed a meta-analysis of randomized controlled trials on this topic but was unable to report any results on African-Americans citing insufficient data. While this may be true, recently Crane and Wallace [134] found no relationship between physical activity and hypertension in African-American women from the south between 25 and 75 years old. In fact, when divided into two groups by age (25 - 45, 46 -75 yrs) the two did not differ on modifiable risk factors which included hypertension. The average SBP and DBP for the younger and older groups were 130.10 mm Hg (SD = 16.37), 126.10 mm Hg (SD = 15.59),

respectively. This supports the assertion of an early onset of hypertension within this community [36].

In pre-hypertensive overweight and obese (mean BMI = 30.8) African-American women between 30 - 45 years of age, no significant decrease was reported following a ten-week aerobic exercise intervention despite an improvement in fitness level [135]. Conversely, in a randomized parallel study of young to middle-aged (18 – 45 yrs) African-American women participating in three ten-minute bouts of exercise throughout the day, a significant decrease in systolic blood pressure (-6.6 mm Hg,  $P = .036$ ) did occur [136]. At the same time, diastolic blood pressure decreased from stage 1 (90.8 mm Hg) to pre-hypertensive levels (87.4 mm Hg) but did not reach statistical significance when compared to control group. The reported decrease in blood pressure was independent of changes in body weight. In a meta-analysis of randomized controlled trials, African-Americans had significant reductions in SBP -10.96(-21.02 to -0.89) and DBP -3.25(-7.11 to 0.60); however, subgroup analysis was unavailable by gender [50].

In conclusion, aerobic exercise can be an effective method of decreasing blood pressure in normo-tensive and hypertensive African-Americans. In addition, exercise is effective lifestyle choice which helps to control blood pressure. Due to the inconsistent results published on blood pressure outcomes based on aerobic exercise, it is apparent that more research is necessary in this cohort [33, 112, 113].

#### **2.4.7 Smoking**

The National Health Interview Survey conducted in 2008 denotes that about 46 million U.S. adults were current cigarette smokers in 2008. The prevalence of smoking by ethnicity is 22.0

(21.1--23.0) in Whites, 21.3 (19.5--23.1) in Blacks, 32.4 (24.--42.6) in American Indians, and 9.9 (7.8--12.6) Asian. Finally, the prevalence among African American women is 17.8 (15.5--20.0) [137].

Smoking has been associated with blood pressure; however, the reported results are indeterminable. For example, smoking lowers blood pressure in some subjects, raises blood pressure in others, and yet has no effect on some individuals.

Okubo, Miyamoto, Suwazono, Kobayashi and Nogawa, [138] conducted a cross-sectional study in Japanese men between 40 and 54 years old. The subjects were clinically normo-tensive (<140/90) based on annual health examinations and subjects taking medication for hypertension were excluded. Subjects were divided into five categories based on smoking habits: non-smokers, ex-smokers, light, moderate, and heavy smokers. Light, moderate, and heavy smokers were classified as those using 1-19, 20-39, and greater than 40 cigarettes per day, respectively. Results from comparing the five categories showed that SBP and DBP were significantly lower in light and moderate smokers compared to non-smokers ( $P<0.001$ ). Further analysis of variables using ANCOVA showed a significant difference in adjusted SBP and DBP of light, moderate, and heavy smokers compared to non-smokers and ex-smokers. On the other hand, when comparing the three smoking groups the difference in blood pressure among the groups was not significant. Similar results in smokers have been reported by [139-142].

The Strong Heart Study examined risk factors for hypertension and hypertension incidence in American Indians [143]. 4549 men and women from 13 Indian tribes in Arizona, North and South Dakota, and Oklahoma were included in this examination. A significant but negative relationship was found between smoking and SBP and DBP and thus, the risk of

becoming hypertensive in smokers was lower when compared to non-smokers [OR=0.809(0.686-0.953; P=0.0111)][143].

A study of over 7000 male Italian factory workers revealed that smokers had a higher SBP than that of non-smokers (127.72 mmHg vs. 127.1 mmHg,  $P < 0.05$ ); however, the difference was reported as clinically insignificant [144]. Conversely, the same study showed a significant decrease in DBP in smokers compared to nonsmokers (83.37 vs. 84.31mmHg;  $P < 0.001$ ). Similar results of increased SBP from smoking were reported by Dyer and colleagues [145].

In a study of 33,860 English men and women by Primatesta and colleagues [140], no overall difference was found in the age-adjusted blood pressures of never and past smokers when compared to current smokers. After adjusting for age, BMI, social class and alcohol intake, the sample was stratified by age and gender and a significant increase in SBP was found only in men older than 45 years who never smoked (139.9mmHg) when compared to current smokers (140.7mmHg) ( $P < 0.05$ ) [140]. A statistically significant difference was found in women who smoked between 1 and 9 cigarettes per day (135.5/72.4mmHg) when compared to those who never smoked (136.8/73.6mmHg,  $P < 0.05$ ). In addition, a significant interaction between BMI and the SBP-smoking relationship was reported in men ( $P = 0.02$ ) [140]. Also, in those subjects who were within the normal range of BMI, smoking was unrelated to hypertension in a population study of Germans, between 18 and 79 years of age [146]. In this study, smoking status was related to BMI and therefore the significant relationships between smoking and hypertension were apparent in the overweight and obese [146].

An association between smoking cessation and hypertension has also been observed in research. For example, in a study of Swedish women, the incidence rate of hypertension among women who stopped smoking was significantly higher (OR=1.8; CI: 1.4-2.5) than current smokers (OR=1.3; CI: 1.07-1.6) [147]. Lee, Ha, Kim, and Jacobs [148] examined this topic in men and found similar results. The author reported that after adjustments for smoking, alcohol, exercise, baseline age, BP and BMI, changes in BMI and alcohol over time, the subjects who stopped smoking had an increased risk of developing hypertension over the four-year follow up period. Hence, the relative risk for those who stopped smoking was 0.6(95%CI: 0.2-1.9) for <1 year, 1.5(95%CI: 0.8-2.8) for 1-3years, 3.5(95%CI: 1.7-7.4)for  $\geq$  3 years [148]. In addition, John et al. [146] reported significant odds of mild hypertension in obese smokers who had not smoked in greater than three years when compared to smokers who smoked more than 15 cigarettes per day [OR=6.5 (95%CI: 2.3-5.7)].

In conclusion, the impact of smoking on hypertension is equivocal. Much of the available research indicates that smoking or individuals who smoke have blood pressure levels which are lower than those who are considered non-smokers and never smokers. Differences in blood pressure levels among smokers based on quantity of cigarettes smoked per day are insignificant. Smoking cessation is not linked to lower blood pressure. Although both smoking and hypertension are known cardiovascular risk factors, a causal relationship between the two can't be made.

## **3.0 METHODS**

### **3.1 INTRODUCTION**

Blood pressure has been shown to be higher at higher levels of body mass index (BMI) [28]. NHANES data of overweight/obesity, for individuals  $\geq 20$  years of age shows that 75.7% of African-Americans are overweight or obese. In addition, data from the 2005-2008 NHANES survey grouped by ethnicity reveals the highest prevalence of hypertension to be among Non-Hispanic Blacks (42.6%). There is some evidence to suggest that blood pressure is reduced with weight loss [101]. There is limited research available on the outcome of changes in blood pressure based on levels of physical activity in overweight and obese African-American women.

### **3.2 SUMMARY OF RESEARCH APPROACH**

Five weight loss studies were combined and data retrospectively analyzed to examine the relationship between both blood pressure and body mass index, and physical activity in overweight and obese African-American women. In addition, the relationship between fitness and blood pressure was also examined.

Common recruitment, eligibility, intervention, and outcome components were identified among the following five completed studies:

- Study 1: Dose-Response of Exercise of Long-Term Weight Loss
- Study 2: Mentor-Based Approach to Long-Term Weight Loss
- Study 3: Enhancing Exercise Participation in Overweight Adults
- Study 4: Evaluation of Alternative Exercise Treatments on Weight Loss in Overweight Women
- Study 5: Role of Exercise in the Prevention of Weight Gain

### **3.3 SUBJECT RECRUITMENT AND SCREENING**

Subjects were recruited from newsletters and newspaper, radio, and TV advertisements which were approved by the Institutional Review Boards of the University of Pittsburgh (Pittsburgh, PA) and The Miriam Hospital (Providence, RI). The racial, gender and ethnic characteristics of the subject population reflected the demographics of the Greater Providence, RI and Pittsburgh, PA and their respective surrounding areas. No exclusion criteria were based on race, ethnicity, gender or HIV status.

Subjects were screened via the telephone. At the time of the screening verbal consent was obtained prior to asking the potential participant any questions during the telephone call. Written informed consent was obtained following the orientation visit and prior to the baseline assessment visit. In addition, written consent was obtained by the subject's primary care physician prior to participation in any aspect of the clinical assessments and intervention for the studies included in this investigation. Eligible subjects participated in baseline assessments which included body weight, body composition, cardiorespiratory fitness, resting blood pressure, resting heart rate and assessment of dietary and exercise behaviors.

Subjects were males and females. However, the secondary analysis proposed for this study will only include females who self-report to be African-American. Thus, a total of 97

subjects were available for this secondary analysis (16 from Study 1, 3 from Study 2, 44 from Study 3, 6 from Study 4, and 28 from Study 5). Subjects were also between 18 and 55 years of age with a BMI ranging from 25 to  $< 40 \text{ kg/m}^2$ . Additional common inclusion and exclusion criteria are listed below in Table 3.1; however, subjects for this research study will only include those participants who have a resting SBP  $\geq 120$  or a resting DBP of  $\geq 90$ .

**Table 3.1. Study Eligibility Requirements**

<b>Inclusion Criteria</b>	<b>Study 1</b>	<b>Study 2</b>	<b>Study 3</b>	<b>Study 4</b>	<b>Study 5</b>
Females included in study	Yes	Yes	Yes	Yes	Yes
18 to 55 years of age	X	X	X	X	X
21-55 year of age					
Body Mass Index (BMI) 25 to <40.0 kg/m <sup>2</sup>	X	X	X	X	
Body Mass Index (BMI) 25 to <30.0 kg/m <sup>2</sup>					X
Ability to provide informed consent	X	X	X	X	X
Ability to provide consent from physician	X	X	X	X	X
<b>Exclusion Criteria</b>	<b>Study 1</b>	<b>Study 2</b>	<b>Study 3</b>	<b>Study 4</b>	<b>Study 5</b>
History of orthopedic complications that would prevent optimal participation in the exercise component (e.g. heel spurs, severe arthritis.)	X	X	X	X	X
Regular exercise participation of at least 20 minutes per day on at least 3 days per week during the previous six months.	X	X	X	X	X
Diabetes, hypothyroidism, or other medical conditions which would affect energy metabolism.	X	X	X	X	X
Currently pregnant, pregnant within previous six months, or planning to become pregnant within the next 24 months.	X	X	X	X	X
Non-medicated resting systolic blood pressure $\geq$ 160 mmHg or non-medicated resting diastolic blood pressure $\geq$ 100 mmHg, or taking medication that would affect blood pressure.	X	X	X	X	X
Taking medication that would affect resting heart rate or the heart rate response during exercise (i.e. beta blockade).	X	X	X	X	X
Arrhythmia on resting or exercise electrocardiogram that would indicate that vigorous exercise was contraindicated.	X	X	X	X	X
History of myocardial infarction or valvular disease.	X	X	X	X	X
Weight loss of > 5% of body weight within the previous 12 months.	X	X	X	X	X

### 3.4 DESIGN AND INTERVENTION OF EACH STUDY

The five studies included in this investigation are randomized trials. A detailed summary of the individual studies is provided below.

#### 3.4.1 Study 1: Dose-Response of Exercise on Long-Term Weight Loss

This study was a randomized clinical trial. All groups received a standard behavioral weight loss program that included the following components.

**Intervention Contact:** Subjects were instructed to attend weekly group meetings for 6 months, with the content of the intervention delivered in a group format consisting of approximately 15-25 participants. Group sessions were scheduled to typically last 55-60 minutes, which permitted time to distribute intervention materials, interact with each participant, identify participants that need additional support, and conduct the group intervention.

**Behavioral Lesson Content:** Each group visit focused on a specific behavioral topic related to weight loss, eating behaviors, or exercise behaviors. Discussion related to this topic was facilitated by the interventionist, and interactive group participation was encouraged. Participants were provided written materials to supplement the group discussion. Individuals who missed an in-person session were mailed all intervention materials and were encouraged to review them prior to the next group meeting.

**Self-Monitoring:** Self-monitoring is an important component of behavioral weight loss interventions. Participants were encouraged to self-monitor their eating and exercise behaviors throughout the intervention period. Participants were provided with a weekly diary to record eating and exercise patterns. Participants returned the completed diary to the intervention staff at

each in-person visit for review, and the intervention staff provided written feedback on the diary prior to it being returned to the participant. The diaries were also used to generate discussion with the participant during the weigh-in period and within the in-person group session. Participants were also provided with self-addressed stamped envelopes to facilitate the return of these diaries in the event that they need to miss an in-person visit. (Note: Participants identified as engaging in eating and exercise behaviors that were deemed to be unsafe were contacted and receive appropriate counseling from the investigators.)

**Dietary Recommendations:** All subjects were prescribed an energy restricted dietary intervention that has shown to effectively reduce body weight by 8-10% within the initial 6 months of treatment. This included reducing energy intake to 1200 to 1500 kcal/d based on initial body weight (<200 pounds = 1200 kcal/d;  $\geq$ 200 = 1500 kcal/d). Dietary fat intake consistent with 20% to 30% of total energy intake was also encouraged. To facilitate the adoption of the dietary recommendations, participants were provided with meal plans that allowed them to plan for modifications in their daily and weekly meal plans, and a calorie counter book.

**Exercise Recommendations:** Subjects were randomized to one of four treatment groups, with the randomization resulting in different intensities and durations of exercise prescribed for each of the four treatment conditions. The exercise prescription for each randomized group is shown in Table 3.3.

**Table 3.3. Dose-Response of Exercise on Long-Term Weight Loss Exercise Prescription for the Four Treatment Groups for 6 Months.**

	<b><u>Exercise Intervention Conditions</u></b>			
	Moderate Intensity/ Moderate Duration	Vigorous Intensity/ Moderate Duration	Moderate Intensity/ High Duration	Vigorous Intensity/ High Duration
Intensity Level (% of HR max)				
Weeks 1-8	50-65%	50-65%	50-65%	50-65%
Weeks 9-16	50-65%	60-75%	50-65%	60-75%
Weeks 16-24	50-65%	70-85%	50-65%	70-85%
Duration (Min/Day)				
Weeks 1-4	20 min/day	20 min/day	20 min/day	20 min/day
Weeks 5-8	30 min/day	30 min/day	30 min/day	30 min/day
Weeks 9-12	40 min/day	30 min/day	40 min/day	40 min/day
Weeks 13-16	40 min/day	30 min/day	50 min/day	40 min/day
Weeks 17-20	40 min/day	30 min/day	60 min/day	40 min/day
Weeks 21-24	40 min/day	30 min/day	60 min/day	40 min/day

### **3.4.2 Study 2: Mentor-Based Approach to Long-Term Weight Loss**

This study was a randomized clinical trial, and subjects were recruited in two phases. Subjects recruited for Phase 1 received a 6 month behavioral weight loss intervention. Subjects recruited for Phase 2 began their treatment 6 months after subjects in Phase 1, with subjects in Phase 2 randomized to receive or not receive additional mentoring (Mentor-Recipient or Non-Mentor-Recipient) from one of the subjects who participated in Phase 1. The additional components of the intervention are described below.

**Intervention Contact:** Similar to Study 1, subjects in Study 2 were instructed to attend weekly group meetings for 6 months, with the content of the intervention delivered in a group format consisting of approximately 15-25 participants. Group sessions were scheduled to typically last 55-60 minutes, which permitted time to distribute intervention materials, interact

with each participant, identify participants that need additional support, and conduct the group intervention.

**Behavioral Lesson Content:** Similar to Study 1, each group visit focused on a specific behavioral topic related to weight loss, eating behaviors, or exercise behaviors. Discussion related to this topic was facilitated by the interventionist, and interactive group participation was encouraged. Participants were provided written materials to supplement the group discussion. Individuals who missed an in-person session were mailed all intervention materials and were encouraged to review them prior to the next group meeting.

**Self-Monitoring:** Similar to Study 1, participants were encouraged to self-monitor their eating and exercise behaviors throughout the intervention period. Participants were provided with a weekly diary to record eating and exercise patterns. Participants returned the completed diary to the intervention staff at each in-person visit for review, and the intervention staff provided written feedback on the diary prior to it being returned to the participant. The diaries were also be used to generate discussion with the participant during the weigh-in period and within the in-person group session. Participants were also provided with self-addressed stamped envelopes to facilitate the return of these diaries in the event that they need to miss an in-person visit. (Note: Participants identified as engaging in eating and exercise behaviors that are deemed to be unsafe were contacted and receive appropriate counseling from the investigators.)

**Dietary Recommendations:** Similar to Study 1, all subjects were prescribed an energy restricted dietary intervention that has shown to effectively reduce body weight by 8-10% within the initial 6 months of treatment. This included reducing energy intake to 1200 to 1500 kcal/d based on initial body weight (<200 pounds = 1200 kcal/d;  $\geq$ 200 = 1500 kcal/d). Dietary fat intake consistent with 20% to 30% of total energy intake was also encouraged. To facilitate the

adoption of the dietary recommendations, participants were provided with meal plans that allowed them to plan for modifications in their daily and weekly meal plans, and a calorie counter book.

**Exercise Recommendations:** All subjects were prescribed exercise that was initially prescribed at 100 minutes of exercise per week (20 minutes per day, 5 days per week) for weeks 1-4. This increased to 150 minutes per week (30 minutes per day, 5 days per week) for weeks 5-8, and the prescription increased to 200 minutes per week (40 minutes per day, 5 days per week) for weeks 9-24. The prescribed intensity of the exercise was moderate (50% to 70% of age-predicted maximal heart rate), which is the equivalent of brisk walking for most individuals.

### **3.4.3 Study 3: Enhancing Exercise Participation in Overweight Adults**

This study was a randomized clinical trial. Eligible subjects were randomized to one of three intervention groups: 1) Standard Behavioral Weight Loss Program (SBWP), 2) SBWP plus Enhanced Exercise Adoption Group (EX-ADOPT), or 3) SBWP plus Enhanced Exercise Maintenance Group (EX-MAINTAIN). The intervention components of the three groups are listed below in Table 3.4 and described in detail in the sections that follow.

**Table 3.4. Enhancing Exercise Participation in Overweight Adults Intervention**

	SBWP	EX-ADOPT	EX-MAINTAIN
<b>INTERVENTION COMPONENTS</b>			
Weekly group intervention meetings for months 1-6	X	X	X
Telephone Contact			
• Weekly during weeks 1-12		X	
• Weekly during weeks 13-24			X
Prescribed reduction in energy intake	X	X	X
Prescribed increase in exercise	X	X	X
Supervised Exercise 1 day per week			
• Months 1-6		X	
• Months 7-12			X
Exercise Promotion Campaign			
• Months 4-9		X	
• Months 13-18			X

**Intervention Contact:** Similar to Studies 1 and 2, subjects in Study 3 were instructed to attend weekly group meetings for 6 months, with the content of the intervention delivered in a group format consisting of approximately 15-25 participants. Group sessions were scheduled to typically last 55-60 minutes, which permitted time to distribute intervention materials, interact with each participant, identify participants that need additional support, and conduct the group intervention.

Subjects in EX-ADOPT and EX-MAINTAIN also received telephone contact. EX-ADOPT received this telephone contact during weeks 1-12 and EX-MAINTAIN received this

telephone contact during weeks 13-24. This telephone call occurred once per week and was to be approximately 10 minutes in duration. To facilitate this call, a predetermined time was arranged with the participant for this call to be completed. The interventionist used a standardized script when conducting this call, with the primary aim being to identify barriers to compliance to recommended changes in eating and exercise behaviors, and to use problem solving techniques to address these barriers.

**Behavioral Lesson Content:** Similar to Studies 1 and 2, each group visit focused on a specific behavioral topic related to weight loss, eating behaviors, or exercise behaviors. Discussion related to this topic was facilitated by the interventionist, and interactive group participation was encouraged. Participants were provided written materials to supplement the group discussion. Individuals who missed an in-person session were mailed all intervention materials and were encouraged to review them prior to the next group meeting.

**Self-Monitoring:** Similar to Studies 1 and 2, participants were encouraged to self-monitor their eating and exercise behaviors throughout the intervention period. Participants were provided with a weekly diary to record eating and exercise patterns. Participants returned the completed diary to the intervention staff at each in-person visit for review, and the intervention staff provided written feedback on the diary prior to it being returned to the participant. The diaries were also used to generate discussion with the participant during the weigh-in period and within the in-person group session. Participants were also provided with self-addressed stamped envelopes to facilitate the return of these diaries in the event that they need to miss an in-person visit. (Note: Participants identified as engaging in eating and exercise behaviors that are deemed to be unsafe were contacted and receive appropriate counseling from the investigators.)

**Dietary Recommendations:** Similar to Studies 1 and 2, all subjects were prescribed an energy restricted dietary intervention that has shown to effectively reduce body weight by 8-10% within the initial 6 months of treatment. This included reducing energy intake to 1200 to 1500 kcal/d based on initial body weight (<200 pounds = 1200 kcal/d;  $\geq$ 200 = 1500 kcal/d). Dietary fat intake consistent with 20% to 30% of total energy intake was also encouraged. To facilitate the adoption of the dietary recommendations, participants were provided with meal plans that allowed them to plan for modifications in their daily and weekly meal plans, and a calorie counter book.

**Exercise Recommendations:** All subjects were prescribed exercise that was initially prescribed at 100 minutes of exercise per week (20 minutes per day, 5 days per week) and progressed by 25 to 50 minutes per week at 4 week intervals until reaching a prescription of 300 minutes per week. The prescribed intensity of the exercise was moderate (50% to 70% of age-predicted maximal heart rate), which is the equivalent of brisk walking for most individuals.

Subjects in EX-ADOPT and EX-MAINTAIN also received supervised exercise sessions with the intervention staff. EX-ADOPT received supervised exercise one day per week during months 1-6 and EX-MAINTAIN received supervised exercise one day per week during months 7-12. These supervised sessions included exercise on treadmills in the Physical Activity and Weight Management Research Center at the University of Pittsburgh.

Subjects in EX-ADOPT and EX-MAINTAIN also received campaigns to promote compliance with the exercise prescription. EX-ADOPT received these campaigns during months 4-9 and EX-MAINTAIN received these campaigns during months 13-18. These campaigns included pedometers with subjects receiving incentive prizes for achievement of activity goals.

### **3.4.4 Study 4: Evaluation of Alternative Exercise Treatments on Weight Loss in**

#### **Overweight Women**

This study was a randomized clinical trial. Eligible subjects were randomized to one of three intervention groups: 1) Standard Behavioral Weight Loss Program (SBWP), 2) SBWP plus Resistance Exercise (SBWP+RT), or 3) SBWP plus Yoga Exercise (SBWP+YOGA).

**Intervention Contact:** Similar to Studies 1, 2, and 3, subjects in Study 4 were instructed to attend weekly group meetings for 6 months, with the content of the intervention delivered in a group format consisting of approximately 15-25 participants. Group sessions were scheduled to typically last 55-60 minutes, which permitted time to distribute intervention materials, interact with each participant, identify participants that need additional support, and conduct the group intervention.

**Behavioral Lesson Content:** Similar to Studies 1-3, each group visit focused on a specific behavioral topic related to weight loss, eating behaviors, or exercise behaviors. Discussion related to this topic was facilitated by the interventionist, and interactive group participation was encouraged. Participants were provided written materials to supplement the group discussion. Individuals who missed an in-person session were mailed all intervention materials and were encouraged to review them prior to the next group meeting.

**Self-Monitoring:** Similar to Studies 1-3, participants were encouraged to self-monitor their eating and exercise behaviors throughout the intervention period. Participants were provided with a weekly diary to record eating and exercise patterns. Participants returned the completed diary to the intervention staff at each in-person visit for review, and the intervention staff provided written feedback on the diary prior to it being returned to the participant. The diaries were also used to generate discussion with the participant during the weigh-in period.

and within the in-person group session. Participants were also provided with self-addressed stamped envelopes to facilitate the return of these diaries in the event that they need to miss an in-person visit. (Note: Participants identified as engaging in eating and exercise behaviors that are deemed to be unsafe were contacted and receive appropriate counseling from the investigators.)

**Dietary Recommendations:** Similar to Studies 1-3, all subjects were prescribed an energy restricted dietary intervention that has shown to effectively reduce body weight by 8-10% within the initial 6 months of treatment. This included reducing energy intake to 1200 to 1500 kcal/d based on initial body weight (<200 pounds = 1200 kcal/d;  $\geq$ 200 = 1500 kcal/d). Dietary fat intake consistent with 20% to 30% of total energy intake was also encouraged. To facilitate the adoption of the dietary recommendations, participants were provided with meal plans that allowed them to plan for modifications in their daily and weekly meal plans, and a calorie counter book.

**Exercise Recommendations:** All subjects were prescribed exercise that was initially prescribed at 100 minutes of exercise per week (20 minutes per day, 5 days per week) and progressed by 50 minutes per week at 4 week intervals until reaching a prescription of 200 minutes per week. The prescribed intensity of the exercise was moderate (50% to 70% of age-predicted maximal heart rate), which is the equivalent of brisk walking for most individuals.

In addition, subjects in SBWP+RT were provided with a home-exercise gym to perform resistance exercise. Subjects were instructed to perform resistance exercise on 3-5 days per week according to a predetermined progression. Subjects in SBWP+YOGA were instructed to perform yoga exercise on 3-5 days per week. Subjects were provided then necessary yoga equipment and yoga videos to follow to perform these activities.

### 3.4.5 Study 5: Role of Exercise in the Prevention of Weight Gain

This was a randomized trial that examined the effectiveness of different doses of prescribed physical activity on body weight regulation in overweight adults. Eligible subjects were randomized to one of three treatment groups: 1) Self-Help, 2) Moderate Exercise Group (MOD-EX), or 3) High Exercise Group (HIGH-EX).

**Intervention Contact:** Similar to Studies 1-4, subjects in MOD-EX and HIGH-EX in Study 5 were instructed to attend weekly group meetings for 6 months, with the content of the intervention delivered in a group format consisting of approximately 15-25 participants. Group sessions were scheduled to typically last 55-60 minutes, which permitted time to distribute intervention materials, interact with each participant, identify participants that need additional support, and conduct the group intervention. Self-Help did not attend in-person intervention sessions during the 6 month intervention period.

**Behavioral Lesson Content:** Similar to Studies 1-4, each week the content of the lesson focused on a specific behavioral topic related to weight control that focused primarily on exercise with some content also focusing on healthy eating behaviors. However, dietary restriction was not prescribed. Within MOD-EX and HIGH-EX, discussion related to this topic was facilitated by the interventionist, and interactive group participation was encouraged. Participants were provided written materials to supplement the group discussion. Individuals who missed an in-person session were mailed all intervention materials and were encouraged to review them prior to the next group meeting. Self-Help received the “Active Living Every Day” manual, a monthly newsletter, and were mailed copies of the weekly behavioral lessons.

**Self-Monitoring:** Participants in MOD-EX and HIGH-EX were encouraged to self-monitor their exercise behaviors throughout the intervention period, and were provided a weekly

diary to record exercise patterns. Participants returned the completed diary to the intervention staff at each in-person visit for review, and the intervention staff provided written feedback on the diary prior to it being returned to the participant. The diaries were also used to generate discussion with the participant during the weigh-in period and within the in-person group session. Participants were also provided with self-addressed stamped envelopes to facilitate the return of these diaries in the event that they need to miss an in-person visit.

**Dietary Recommendations:** Unlike Studies 1-5, subjects in Study 6 were not prescribed an energy restricted diet. Rather, they were provided with information related to healthy eating that were consistent with the US Dietary Guidelines and the Food Guide Pyramid.

**Exercise Recommendations:** Subjects in the MOD-EX group were instructed to engage in moderate intensity exercise of 5 days per week. The total duration per day began at 20 minutes per day and gradually progressed to 30 minutes per day. Subjects in the HIGH-EX group were instructed to engage in moderate intensity exercise of 5 days per week. The total duration per day began at 20 minutes per day and gradually progressed to 60 minutes per day. Subjects in MOD-EX and HIGH-EX were instructed to participate in activity that was at least moderate in intensity, with intensity set at a minimum of 11-13 on the 15-point RPE scale and/or heart rate prescribed at 55-70% of maximal heart rate.

### 3.5 COMMON OUTCOMES MEASURES

The common outcome measures included in the studies which will also be used in this secondary analysis are included below in Table 3.5. A detailed description of each outcome measure is also provided below.

**Table 3.5. Common Study Outcomes**

	Study 1	Study 2	Study 3	Study 4	Study 5
Weight/Height/Body Mass Index	X	X	X	X	X
Waist Circumference	X	X	X	X	X
Cardiorespiratory Fitness	X	X	X	X	X
Physical Activity	X	X	X	X	X
Resting Blood Pressure	X	X	X	X	X

### **3.5.1 Body Mass Index**

The primary outcome of the three studies is weight loss. Body weight was measured to the nearest 0.25 lb using a calibrated medical balance-beam scale and converted to kilograms. For assessment of body weight and height subjects were only clothed in a lightweight cloth hospital gown. Height was measured to the nearest 0.1 centimeter using a wall-mounted stadiometer. Body mass index was computed from measurements of weight and computed as  $\text{kg}/\text{m}^2$ .

### **3.5.2 Waist Circumference**

Girth measures of the waist were performed by taking a horizontal circumference at the level of the umbilicus. The subject was measured using a lightweight cloth hospital gown with other clothing removed. Measurements were performed using a Gulick tape measures, with two measurements taken that differed by  $<2$  cm. The average of these two measurements was used to represent the waist girth.

### **3.5.3 Bioelectrical Impedance Analyzer (BIA)**

Body composition was assessed using Bioelectrical Impedance Analysis (BIA). The tetrapolar method was used and 4 small electrodes were placed on the hand, wrist, ankle and foot on the right side of the body. A low-level electrical current was then transmitted between the electrodes to measure impedance, or the opposition to the flow of the current through the body. From this value, fat-free mass was calculated using an equation by Segal et al. [149] and this was converted to percent body fat using the following equation:

$$\text{Percent body fat} = [(\text{weight} - \text{lean body mass}) / \text{weight}] * 100$$

### **3.5.4 Blood Pressure**

Subjects were fitted with a standard blood pressure cuff with the size of the cuff determined based on measurement of the circumference of the upper arm at the mid-point between the olecranon and acromion processes. Subjects were then placed in a seated resting position for a period of 5-10 minutes and were instructed to relax and keep movement to a minimum. Following this rest period, resting blood pressure was assessed using a manual sphygmomanometer. Blood pressure was measured in duplicate with two measurements that differed by  $\leq 10$  mmHg for systolic blood pressure and  $\leq 6$  mmHg for diastolic blood pressure.

### **3.5.5 Cardiorespiratory Fitness**

A modified Stanford treadmill protocol was used for exercise testing [150]. The speed of the treadmill was kept constant at 3.0 mph (80.4 m/min) with the initial grade of the treadmill being 0% and increasing at 2.5% increments at 3-minute intervals. During this exercise test, subjects breathed through a mass flow sensor with expired gas volumes and concentrations being measured continuously using a SensorMedics V-Max Metabolic Measuring Cart. Prior to each test, this metabolic cart was calibrated with known gas volumes and concentrations according to the procedures recommended by the manufacturer. Heart rate during exercise testing was obtained at one-minute intervals using a 12-lead ECG (Marquette Instruments) and immediately upon termination of the exercise test. In addition, blood pressure was assessed during the last minute of each stage and at the point of test termination. Ratings of perceived exertion were assessed during the last 15 seconds of each stage and at the point of termination using the 16 point Borg Scale (RPE=6-20). The test will be terminated at the point the subject achieves 85% of age-predicted maximal heart rate. In addition, the ACSM criteria for test termination will be followed. Following termination of the test, the subject had a 5 to 10-minute recovery period to insure that heart rate and blood pressure have returned to pretesting levels. A certified physician trained in ECG interpretation evaluated the results of each test to insure that exercise training was not contraindicated.

### **3.5.6 Physical Activity**

Physical activity was assessed using the Exercise Habits Questionnaire developed by Paffenbarger et al. [151]. This questionnaire provides an estimate of leisure-time physical

activity. Subjects were queried on the flights of stairs they climb up per day, blocks walked per day, and any additional sport, recreational, or fitness activities performed during the prior typical week. Activities were coded using the Compendium of Physical Activities [152]. Data were used to compute weekly energy expenditure and minutes of weekly moderate-to-vigorous weekly physical activity.

### **3.6 STATISTICAL ANALYSIS**

Statistical analysis was performed using SPSS for Windows 17.0. Data were tested to determine if assumptions of normality were achieved. If the data did not meet the assumptions of normality nonparametric equivalents were used. Statistical significance was defined as  $p < 0.05$ . Descriptive data are presented as means, standard deviations and ranges. Changes from baseline to 6 months for body weight, BMI, waist girth, cardiorespiratory fitness, physical activity, and resting systolic and diastolic blood pressure were examined using dependent t-tests.

The hypotheses for specific aims 1 and 2 were tested through the use of linear regression. The hypothesis for specific aim 3 was tested by linear regression with physical activity added to each of the models to determine the potential mediation effect. The hypothesis for specific aim 4 was tested by linear regression with cardiorespiratory fitness added to each of the models to determine the potential mediation effect.

The analysis was initially performed unadjusted. An additional analysis was performed and adjustments made for the following independent variables: smoking status and age. The effect of total physical activity was also examined.

The analysis of SBP was only inclusive of those individuals with a resting SBP  $\geq 120$  mm Hg and the analysis of DBP only included those with a resting DBP  $\geq 80$  mm Hg.

### **3.7 POWER ANALYSIS**

The primary hypothesis in this study was examined using linear regression and represented as correlation coefficients. Data from 97 African-American women with complete data for analysis in this were available from the 5 studies described earlier (16 from Study 1, 3 from Study 2, 44 from Study 3, 6 from Study 4, and 28 from Study 5). Based on this available sample, significant correlations of  $r=0.35$  are able to be detected with alpha set at 0.05 and with 95% statistical power. If statistical power is adjusted to 80%, this permitted detection of significant correlations of  $r=0.28$  with alpha set at 0.05 for the primary analyses in this study. Moreover, this allowed for an effect size of 0.58 to be detected for changes from baseline to 6 months for the outcome variables for this study with 80% statistical power and alpha set at 0.05.

## 4.0 RESULTS

### 4.1 DESCRIPTIVE CHARACTERISTICS OF SUBJECTS

Baseline descriptive data for the 97 African-American women included in this study are shown in Table I, with data presented as means  $\pm$  standard deviations. At baseline the subjects were  $41.5 \pm 7.7$  years of age, body mass index (BMI) of  $31.4 \pm 4.0$  kg/m<sup>2</sup>, percent body fat of  $40.2 \pm 4.8\%$  and waist circumference of  $100.5 \pm 11.9$  cm. Self-reported leisure-time physical activity was  $588.1 \pm 635$  kcal/wk with graded exercise testing time  $9.1 \pm 4.3$  min. Resting systolic (SBP) and diastolic blood pressure (DBP) was  $118.1 \pm 10.9$  mmHg and  $77.7 \pm 8.2$  mmHg, respectively. Of the 97 subjects, 40 were identified that had a resting SBP  $\geq 120$  mmHg at baseline and 35 subjects were identified that had a resting DBP  $\geq 80$  mmHg.

**Table 4.1: Descriptive characteristics of subjects.**

Variable	Total Sample (N=97)	Subjects with a baseline resting systolic blood pressure $\geq$ 120 mmHg (N=40)	Subjects with a baseline resting diastolic blood pressure $\geq$ 80 mmHg (N=35)
Age (years)	41.5 $\pm$ 7.7	43.8 $\pm$ 7.4	43.8 $\pm$ 7.6
Height (cm)	165.7 $\pm$ 6.4	165.2 $\pm$ 6.1	165.0 $\pm$ 5.9
Weight (kg)	86.3 $\pm$ 12.1	91.0 $\pm$ 10.1	89.9 $\pm$ 12.1
Body Mass Index (kg/m <sup>2</sup> )	31.4 $\pm$ 4.0	33.4 $\pm$ 3.4	33.0 $\pm$ 3.9
Waist Circumference (cm)	100.5 $\pm$ 11.9	105.7 $\pm$ 11.5	105.3 $\pm$ 12.3
Percent Body Fat	40.2 $\pm$ 4.8	42.6 $\pm$ 3.9	42.0 $\pm$ 4.9
Physical Activity (kcal/wk)	588.1 $\pm$ 635.0	559.5 $\pm$ 473.6	509.0 $\pm$ 473.6
Graded Exercise Test (minutes)	9.1 $\pm$ 4.3	7.5 $\pm$ 4.4	7.5 $\pm$ 4.3
Resting Systolic Blood Pressure (mmHg)	118.1 $\pm$ 10.9	128.2 $\pm$ 8.2	124.8 $\pm$ 10.0
Resting Diastolic Blood Pressure (mmHg)	77.7 $\pm$ 8.2	82.6 $\pm$ 7.7	86.1 $\pm$ 5.7

## 4.2 INTERVENTION EFFECTS

The subjects included in this study participated in one of 5 weight loss intervention studies that had similar approaches to modifying eating behaviors and physical activity. The effects of these interventions on key variables pertinent to this current study are shown in Table 4.2. These interventions resulted in significant ( $p < 0.001$ ) decreases in body weight, BMI, waist circumference, and percent body fat. Both physical activity and fitness, represented as the time to achieve 85% of age-predicted maximal heart rate on a graded exercise test, both significantly increased in response to the interventions ( $p < 0.001$ ). Moreover, resting SBP decreased  $4.4 \pm 10.9$  mmHg ( $p < 0.001$ ) and resting DBP decreased  $2.8 \pm 7.7$  mmHg ( $p < 0.001$ ). Similar patterns of

results were observed when only considering subjects with a resting SBP of  $\geq 120$  mmHg at baseline (see Table 4.3) or subjects with a resting DBP of  $\geq 80$  mmHg at baseline (see Table 4.4).

**Table 4.2: Change in descriptive characteristics of subjects (N=97)**

Variable	Baseline	6 Months	Difference	P-Value
Age (years)	41.5 $\pm$ 7.7			
Height (cm)	165.7 $\pm$ 6.4			
Weight (kg)	86.3 $\pm$ 12.1	82.1 $\pm$ 11.0	5.0 $\pm$ 5.9	<0.001
Body Mass Index (kg/m <sup>2</sup> )	31.4 $\pm$ 4.0	29.6 $\pm$ 3.8	1.8 $\pm$ 2.1	<0.001
Waist Circumference (cm)	100.5 $\pm$ 11.9	95.0 $\pm$ 11.6	5.5 $\pm$ 8.1	<0.001
Percent Body Fat	40.2 $\pm$ 4.8	37.2 $\pm$ 5.4	2.9 $\pm$ 3.6	<0.001
Physical Activity (kcal/wk)	588.1 $\pm$ 635.0	1670.2 $\pm$ 1316.5	1082.1 $\pm$ 1366.5	<0.001
Graded Exercise Test (minutes)	9.1 $\pm$ 4.3	11.5 $\pm$ 4.0	2.5 $\pm$ 3.5	<0.001
Resting Systolic Blood Pressure (mmHg)	118.1 $\pm$ 10.9	113.7 $\pm$ 11.4	4.4 $\pm$ 10.9	<0.001
Resting Diastolic Blood Pressure (mmHg)	77.7 $\pm$ 8.2	74.9 $\pm$ 7.8	2.8 $\pm$ 7.7	<0.001

**Table 4.3: Change in descriptive characteristics of subjects with a resting systolic blood pressure  $\geq 120$  mmHg at baseline (N=40).**

Variable	Baseline	6 Months	Difference	P-Value
Age (years)	43.8 $\pm$ 7.4			
Height (cm)	165.2 $\pm$ 6.1			
Weight (kg)	91.0 $\pm$ 10.1	84.0 $\pm$ 9.9	7.0 $\pm$ 6.5	<0.001
Body Mass Index (kg/m <sup>2</sup> )	33.4 $\pm$ 3.4	30.8 $\pm$ 3.6	2.6 $\pm$ 2.3	<0.001
Waist Circumference (cm)	105.7 $\pm$ 11.5	99.0 $\pm$ 12.0	6.6 $\pm$ 8.9	<0.001
Percent Body Fat	42.6 $\pm$ 3.9	38.8 $\pm$ 4.8	3.8 $\pm$ 3.8	<0.001
Physical Activity (kcal/wk)	559.5 $\pm$ 473.6	1777.3 $\pm$ 1414.2	1217.9 $\pm$ 1412.1	<0.001
Graded Exercise Test (minutes)	7.5 $\pm$ 4.4	10.6 $\pm$ 3.6	3.1 $\pm$ 3.0	<0.001
Resting Systolic Blood Pressure (mmHg)	128.2 $\pm$ 8.2	119.6 $\pm$ 11.9	8.6 $\pm$ 13.0	<0.001
Resting Diastolic Blood Pressure (mmHg)	82.6 $\pm$ 7.7	77.8 $\pm$ 8.3	4.8 $\pm$ 8.9	<0.001

**Table 4.4: Change in descriptive characteristics of subjects with a resting diastolic blood pressure  $\geq 80$  mmHg at baseline (N=35).**

Variable	Baseline	6 Months	Difference	P-Value
Age (years)	43.8 $\pm$ 7.6			
Height (cm)	165.0 $\pm$ 5.9			
Weight (kg)	89.9 $\pm$ 12.1	83.5 $\pm$ 11.3	6.2 $\pm$ 6.3	<0.001
Body Mass Index (kg/m <sup>2</sup> )	33.0 $\pm$ 3.9	30.7 $\pm$ 3.8	2.3 $\pm$ 2.2	<0.001
Waist Circumference (cm)	105.3 $\pm$ 12.3	99.1 $\pm$ 11.5	6.2 $\pm$ 8.6	<0.001
Percent Body Fat	42.0 $\pm$ 4.9	38.6 $\pm$ 5.8	3.4 $\pm$ 3.9	<0.001
Physical Activity (kcal/wk)	509.0 $\pm$ 473.6	1600.7 $\pm$ 1475.2	1091.7 $\pm$ 1398.1	<0.001
Graded Exercise Test (minutes)	7.5 $\pm$ 4.3	10.3 $\pm$ 4.6	2.7 $\pm$ 3.3	<0.001
Resting Systolic Blood Pressure (mmHg)	124.8 $\pm$ 10.0	120.3 $\pm$ 10.9	4.5 $\pm$ 10.8	0.019
Resting Diastolic Blood Pressure (mmHg)	86.1 $\pm$ 5.7	80.0 $\pm$ 7.0	6.1 $\pm$ 8.0	<0.001

**Table 4.5: Correlations between change in blood pressure and change in measures of body weight, body composition, physical activity and fitness (N=97).**

Change in Blood Pressure Variable	Change in Other Variables	Correlation Coefficient (p-value)	Controlling for Smoking (p-value)	Controlling for Change in Physical Activity (p-value)	Controlling for Change in Physical Activity and Smoking (p-value)	Controlling for Change in Fitness (p-value)	Controlling for Change in Fitness and Smoking (p-value)
Resting Systolic Blood Pressure (mmHg)	Weight (kg)	0.225 (0.027)	0.223 (0.030)	0.188 (0.066)	0.183 (0.078)	0.122 (0.237)	0.107 (0.304)
	Body Mass Index (kg/m <sup>2</sup> )	0.230 (0.024)	0.228 (0.026)	0.190 (0.064)	0.185 (0.074)	0.123 (0.231)	0.110 (0.293)
	Waist Circumference (cm)	0.320 (0.001)	0.323 (0.001)	0.291 (0.004)	0.293 (0.004)	0.261 (0.010)	0.262 (0.011)
	Percent Body Fat	0.189 (0.064)	0.187 (0.070)	0.149 (0.148)	0.143 (0.170)	0.097 (0.345)	0.082 (0.432)
	Physical Activity (kcal/wk)	-0.163 (0.111)	-0.170 (0.100)				
	Graded Exercise Test (minutes)	-0.296 (0.003)	-0.310 (0.002)				
Resting Diastolic Blood Pressure (mmHg)	Weight (kg)	0.213 (0.036)	0.225 (0.028)	0.161 (0.117)	0.173 (0.095)	0.071 (0.491)	0.079 (0.448)
	Body Mass Index (kg/m <sup>2</sup> )	0.225 (0.026)	0.237 (0.021)	0.169 (0.099)	0.182 (0.080)	0.080 (0.436)	0.089 (0.393)
	Waist Circumference (cm)	0.208 (0.041)	0.216 (0.036)	0.161 (0.117)	0.172 (0.098)	0.119 (0.250)	0.130 (0.212)
	Percent Body Fat	0.182 (0.074)	0.202 (0.050)	0.127 (0.219)	0.147 (0.157)	0.059 (0.568)	0.074 (0.478)
	Physical Activity (kcal/wk)	-0.214 (0.035)	-0.209 (0.042)				
	Graded Exercise Test (minutes)	-0.381 (0.000)	-0.375 (0.000)				

### 4.3 ASSOCIATIONS BETWEEN CHANGE IN RESTING BLOOD PRESSURE FOR TOTAL SAMPLE (N=97)

#### 4.3.1 Resting Systolic Blood Pressure

Correlation coefficients representing the relationship between the change in resting SBP and change in weight, BMI, waist circumference, percent body fat, physical activity, and fitness are presented in Table 4.5. Significant correlations were observed between change in resting SBP and change in weight ( $r=0.225$ ,  $p=0.027$ ), BMI ( $r=0.230$ ,  $p=0.024$ ), waist circumference ( $r=0.320$ ,  $p=0.001$ ), and fitness ( $r=-0.296$ ,  $p=0.003$ ). When adjusted for number of cigarettes smoked per day reported at baseline and following 6 months of the intervention the observed correlations were relatively unchanged.

Analyses were performed to determine if controlling for change in physical activity would influence the associations between change in resting SBP and change in weight, BMI, and waist circumference. These analyses showed that when adjusting for change in physical activity, the association between change in resting SBP and change in both weight and BMI were no longer statistically significant, suggesting that change in physical activity fully mediates those relationships. However, change in physical activity partially mediated the relationship between waist circumference and SBP, which is reflected in a correlation of  $r=0.291$  ( $p=0.004$ ) compared to the unadjusted correlation of  $r=0.320$  ( $p=0.001$ ). Further adjustment for smoking did not alter the pattern of these results.

Analyses were also performed to determine if controlling for change in fitness would influence the associations between change in resting SBP and change in weight, BMI, and waist circumference. These analyses showed that adjusting for change in fitness resulted in the

associations between change in resting SBP and change in weight ( $r=0.122$ ,  $p=0.237$ ), BMI ( $r=0.123$ ,  $p=0.231$ ) to no longer be statistically significant, indicating the change in fitness mediates these relationships. However, when adjusting for fitness, the relationship between change in resting SBP and change in waist circumference remained statistically significant ( $r=0.261$ ,  $p=0.010$ ), suggesting that change in fitness partially mediated this relationship. Further adjustment for smoking did not influence the pattern of these findings.

### **4.3.2 Resting Diastolic Blood Pressure**

Correlation coefficients representing the relationship between the change in resting DBP and changes in weight, BMI, waist circumference, percent body fat, physical activity, and fitness are presented in Table 4.5. Significant correlations were observed between the change in resting DBP and changes in weight ( $r=0.213$ ,  $p=0.036$ ), BMI ( $r=0.225$ ,  $p=0.026$ ), waist circumference ( $r=0.208$ ,  $p=0.041$ ), physical activity ( $r=-0.214$ ,  $p=0.035$ ), and fitness ( $r=-0.381$ ,  $p=0.000$ ). The association between percent body fat and DBP became statistically significant ( $r=0.202$ ,  $p=0.050$ ) after adjusting for smoking.

Analyses were performed to examine whether controlling of change in physical activity would influence the associations between the change in resting DBP and changes in weight, BMI, waist circumference, percent body fat. These analyses showed that when adjusting for the change in physical activity that the associations between the change in resting DBP and changes in weight ( $r=0.161$ ,  $p=0.117$ ), BMI ( $r=0.169$ ,  $p=0.099$ ), waist circumference ( $r=0.161$ ,  $p=0.117$ ), and percent body fat ( $r=0.127$ ,  $p=0.219$ ) were no longer statistically significant. Further adjustment for smoking had no meaningful effect on the observed associations. Thus, these results suggest that in overweight and obese African-American women, increases in physical

activity fully mediate the association between reductions in resting DBP and reductions in weight, BMI, waist circumference, and percent body fat.

Analyses were also performed to examine whether controlling for change in fitness would influence the associations between the change in resting DBP and the changes in weight, BMI, waist circumference, percent body fat. These analyses showed that adjusting for the change in fitness resulted in associations between the change in resting DBP and changes in weight ( $r=0.071$ ,  $p=0.491$ ), BMI ( $r=0.080$ ,  $p=0.436$ ), waist circumference ( $r=0.119$ ,  $p=0.250$ ), and percent body fat ( $r=0.059$ ,  $p=0.568$ ) to no longer be statistically significant, suggesting that the change in fitness fully mediates these relationships. Further adjustment for smoking had no meaningful effect on the observed associations.

#### **4.4 ASSOCIATIONS BETWEEN CHANGE IN RESTING BLOOD PRESSURE FOR SUBJECTS WITH A BASELINE RESTING SYSTOLIC BLOOD PRESSURE $\geq 120$ MMHG (N=40)**

##### **4.4.1 Resting Systolic Blood Pressure**

Correlation coefficients representing the relationship between the change in resting SBP and the changes in weight, BMI, waist circumference, percent body fat, physical activity, and fitness are presented in Table 4.6. Significant correlations were observed between the change in resting SBP and changes in waist circumference ( $r=0.402$ ,  $p=0.010$ ), physical activity ( $r=-0.470$ ,  $p=0.002$ ), and fitness ( $r=-0.434$ ,  $p=0.005$ ). When adjusted for smoking that pattern of the findings was unchanged.

An analysis was performed to examine whether controlling for the change in physical activity would influence the association between the change in resting SBP and change in waist circumference. This analysis showed that when adjusting for the change in physical activity, the association between the change in resting SBP and the change in waist circumference ( $r=0.285$ ,  $p=0.079$ ) was no longer statistically significant. Further adjustment for smoking did not influence this finding. These results suggest that in overweight and obese African-American women, increases in physical activity fully mediate the association between reductions in resting SBP and reductions in waist circumference.

Analyses were also performed to examine the influence of the change in fitness on the association between change in resting SBP and change in waist circumference. This analysis showed that when adjusting for the change in fitness there was no longer a significant association between the change in resting SBP and the change in waist circumference ( $r=0.255$ ,  $p=0.117$ ). The results suggest that in overweight and obese African-American women, increases in fitness fully mediate the relationship between reductions in SBP and reductions in waist circumference.

#### **4.4.2 Resting Diastolic Blood Pressure**

Correlation coefficients representing the relationship between the change in resting DBP and changes in weight, BMI, waist circumference, percent body fat, physical activity, and fitness are presented in Table 4.6. Significant correlations were observed between change in resting DBP and changes in waist circumference ( $r=0.402$ ,  $p=0.010$ ), physical activity ( $r=-0.470$ ,  $p=0.002$ ), and fitness ( $r=-0.434$ ,  $p=0.005$ ). When adjusted for smoking, the correlations between DBP and weight ( $r=0.355$ ,  $p=0.019$ ) and BMI ( $r=0.337$ ,  $p=0.027$ ) became statistically significant and in percent body fat ( $r=0.299$ ,  $p=0.052$ ) there was a trend toward significance. Adjusting for smoking

resulted in the relationships between DBP and waist circumference (0.366,  $p=0.016$ ), physical activity ( $r=-0.512$ ,  $p=0.001$ ), and fitness ( $r=-0.431$ ,  $p=0.007$ ) to remain statistically significant.

Analyses were performed to determine whether the change in physical activity or the change in fitness influenced the association between change in resting DBP and change in weight, BMI, and waist circumference. When adjusting for change in physical activity, the associations between the change in resting DBP and the change in weight, BMI, and waist circumference were no longer statistically significant (see Table 4.6). When adjusted for the change in fitness, the relationships between the change in resting DBP and the change in weight, BMI, and waist circumference were also no longer statistically significant. Thus, these findings suggest that in overweight and obese African-American women with a resting SBP  $\geq 120$  mmHg, increases in physical activity and fitness fully mediate the association between the reduction in resting DBP and the reductions in weight, BMI, and, waist circumference.

#### **4.5 ASSOCIATIONS BETWEEN CHANGE IN RESTING BLOOD PRESSURE FOR SUBJECTS WITH A BASELINE RESTING DIASTOLIC BLOOD PRESSURE $\geq 80$ MMHG (N=35)**

##### **4.5.1 Resting Systolic Blood Pressure**

Correlation coefficients representing the relationship between the change in resting SBP and the change in weight, BMI, waist circumference, percent body fat, physical activity, and fitness are presented in Table 4.7. A significant correlation was observed between the change in resting SBP and change in physical activity ( $r=-0.387$ ,  $p=0.012$ ). When adjusted for number of

cigarettes smoked per day at reported at baseline and following 6 months of the intervention the observed correlation was relatively unchanged. There was a trend toward significance for the correlation between the change in resting SBP and both the change in fitness ( $r=-0.311$ ,  $p=0.069$ ) and waist circumference ( $r=0.305$ ,  $p=0.075$ ). However, after controlling for smoking, waist circumference reached statistical significance ( $r=0.343$ ,  $p=0.050$ ). The relationships between the change in SBP and change in weight, BMI, or percent body fat were not statistically significant.

An analysis was performed to examine the effect of change in physical activity on the association between the change in resting SBP and change in waist circumference. The analyses showed that when adjusting for the change in physical activity the association is eliminated between the change in resting SBP and change in waist circumference. Further adjustment for smoking had no meaningful effect on the observed association. Thus, these results suggesting that in overweight and obese African-American women with a resting DBP  $\geq 80$  mmHg, increases in physical activity mediate the association between reductions in resting SBP and reductions in waist circumference.

An analyses was also performed to examine the effect of the change in fitness on the association between the change in resting SBP and change in waist circumference. The analysis showed that when adjusting for the change in fitness there was no significant association between change in resting SBP and change in waist circumference. Hence, the change in fitness is a complete mediator in this relationship.

#### **4.5.2 Resting Diastolic Blood Pressure**

Correlation coefficients representing the relationship between the change in resting DBP and change in weight, BMI, waist circumference, percent body fat, physical activity, and fitness are presented in Table VII. Significant correlations were observed between the change in resting DBP and the change in physical activity ( $r=-0.441$ ,  $p=0.008$ ), and a trend toward significance for change in DBP and change in fitness ( $r=-0.299$ ,  $p=0.081$ ). When adjusted for number of cigarettes smoked per day at reported at baseline and following 6 months of the intervention the observed correlation was relatively unchanged.

**Table 4.6: Correlations between change in blood pressure and change in measures of body weight, body composition, physical activity and fitness for subjects with a resting systolic blood pressure at baseline  $\geq 120$  mmHg (N=40).**

Change in Blood Pressure Variable	Change in Other Variables	Correlation Coefficient (p-value)	Controlling for Smoking (p-value)	Controlling for Change in Physical Activity (p-value)	Controlling for Change in Physical Activity and Smoking (p-value)	Controlling for Change in Fitness (p-value)	Controlling for Change in Fitness and Smoking (p-value)
Resting Systolic Blood Pressure (mmHg)	Weight (kg)	0.201 (0.214)	0.251 (0.105)	0.030 (0.858)	0.012 (0.942)	-0.035 (0.834)	-0.059 (0.728)
	Body Mass Index (kg/m <sup>2</sup> )	0.208 (0.197)	0.246 (0.111)	0.014 (0.933)	-0.004 (0.979)	-0.045 (0.787)	-0.070 (0.682)
	Waist Circumference (cm)	0.402 (0.010)	0.434 (0.004)	0.285 (0.079)	0.287 (0.085)	0.255 (0.117)	0.253 (0.131)
	Percent Body Fat	0.216 (0.182)	0.231 (0.136)	0.027 (0.872)	-0.010 (0.954)	0.025 (0.882)	-0.011 (0.948)
	Physical Activity (kcal/wk)	-0.470 (0.002)	-0.495 (0.002)				
	Graded Exercise Test (minutes)	-0.434 (0.005)	-0.452 (0.004)				
Resting Diastolic Blood Pressure (mmHg)	Weight (kg)	0.228 (0.158)	0.355 (0.019)	0.045 (0.785)	0.052 (0.759)	-0.008 (0.962)	0.007 (0.968)
	Body Mass Index (kg/m <sup>2</sup> )	0.208 (0.197)	0.337 (0.027)	0.045 (0.784)	0.051 (0.762)	0.001 (0.994)	0.016 (0.924)
	Waist Circumference (cm)	0.402 (0.010)	0.366 (0.016)	0.096 (0.562)	0.111 (0.511)	0.070 (0.673)	0.090 (0.595)
	Percent Body Fat	0.216 (0.182)	0.299 (0.052)	0.034 (0.839)	0.041 (0.808)	0.045 (0.786)	0.062 (0.716)
	Physical Activity (kcal/wk)	-0.470 (0.002)	-0.512 (0.001)				
	Graded Exercise Test (minutes)	-0.434 (0.005)	-0.431 (0.007)				

**Table 4.7: Correlations between change in blood pressure and change in measures of body weight, body composition, physical activity and fitness for subjects with a resting diastolic blood pressure at baseline  $\geq 80$  mmHg (N=35).**

Change in Blood Pressure Variable	Change in Other Variables	Correlation Coefficient (p-value)	Controlling for Smoking (p-value)	Controlling for Change in Physical Activity (p-value)	Controlling for Change in Physical Activity and Smoking (p-value)	Controlling for Change in Fitness (p-value)	Controlling for Change in Fitness and Smoking (p-value)
Resting Systolic Blood Pressure (mmHg)	Weight (kg)	0.144 (0.408)	0.175 (0.329)	-0.027 (0.878)	0.005 (0.979)	-0.030 (0.866)	-0.001 (0.997)
	Body Mass Index (kg/m <sup>2</sup> )	0.146 (0.402)	0.177 (0.325)	-0.043 (0.808)	-0.013 (0.943)	-0.37 (0.836)	-0.008 (0.964)
	Waist Circumference (cm)	0.305 (0.075)	0.343 (0.050)	0.209 (0.236)	0.253 (0.162)	0.230 (0.191)	0.271 (0.133)
	Percent Body Fat	0.114 (0.515)	0.138 (0.444)	-0.079 (0.656)	-0.067 (0.717)	-0.019 (0.916)	-0.001 (0.997)
	Physical Activity (kcal/wk)	-0.387 (0.012)	-0.416 (0.016)				
	Graded Exercise Test (minutes)	-0.311 (0.069)	-0.332 (0.059)				
Resting Diastolic Blood Pressure (mmHg)	Weight (kg)	0.188 (0.279)	0.197 (0.271)	-0.003 (0.988)	0.016 (0.932)	0.033 (0.854)	0.046 (0.802)
	Body Mass Index (kg/m <sup>2</sup> )	0.193 (0.267)	0.203 (0.258)	-0.017 (0.923)	0.001 (0.998)	0.031 (0.862)	0.045 (0.808)
	Waist Circumference (cm)	0.181 (0.297)	0.195 (0.278)	0.049 (0.781)	0.072 (0.694)	0.097 (0.586)	0.115 (0.532)
	Percent Body Fat	0.184 (0.289)	0.198 (0.269)	-0.024 (0.893)	-0.011 (0.953)	0.068 (0.701)	0.083 (0.651)
	Physical Activity (kcal/wk)	-0.441 (0.008)	-0.448 (0.009)				
	Graded Exercise Test (minutes)	-0.299 (0.081)	-0.302 (0.088)				

## 5.0 DISCUSSION

### 5.1 CHANGE IN BLOOD PRESSURE IN RESPONSE TO A BEHAVIORAL WEIGHT LOSS INTERVENTION IN AFRICAN-AMERICAN WOMEN.

This study showed that in response to a behavioral weight loss intervention that includes both energy restriction and increased in physical activity, African-American women reduced body weight by  $5.0 \pm 5.9$  kg over a period of 6 months. This weight loss was accompanied by significant decreases in resting systolic blood pressure (SBP) of  $4.4 \pm 10.9$  mmHg and diastolic blood pressure (DBP) of  $2.8 \pm 7.7$  mmHg (see Table 4.2). The magnitude of decrease in SBP was  $8.6 \pm 13.0$  mmHg when only those participants with an initial SBP  $\geq 120$  mmHg were examined (see Table 4.3). Moreover, the magnitude of the decrease in DBP was  $6.1 \pm 8.0$  mmHg when only those with an initial DBP of  $\geq 80$  were examined (see Table 4.4).

Few studies have reported the effects of weight loss on changes in blood pressure specifically for African-American women. One study that has reported these findings showed that a 6-month lifestyle intervention resulted in weight loss of 3.2 kg, and this coincided with a significant reduction in SBP of 1.2 mmHg, with no significant change in DBP [153]. When the DASH diet, a low sodium diet rich in fruits, vegetables, whole grains and reduced dairy products, saturated and total fat, and cholesterol was added to the lifestyle intervention, weight

loss remained at approximately 3.2 kg. This coincided with a reduction in SBP of 2.1 mmHg, with again no significant reduction in DBP in African-American women.

Thus, the current study was able to demonstrate a greater weight loss, and a greater reduction in both SBP and DBP compared to the results reported by Svetkey et al. [153] in African-American women. This may suggest that the magnitude of weight loss is important for maximizing reductions in blood pressure in African-American women. In fact, in a study of un-medicated high normal and stage 1 -2 hypertensive men and women, 23% of which were African-American, a lifestyle intervention resulted in 7.8 kg of weight loss [100]. This magnitude of weight loss coincided with reductions in SBP and DBP of 7.4 mmHg and 5.0 mmHg, respectively. Elmer, Obarzanek, Vollmer, Stimmons, and Stevens [154] also observed a decrease in SBP of 10.5 mmHg and 5.5 mmHg in DBP following a behavioral intervention that resulted in 4.9 kg of weight loss in pre-hypertensive men and women (34% African-Americans) at 6 months.

The importance of weight loss on blood pressure control is further supported by the findings of Juhaeri et al. [155] who reported from prospective data that weight loss of 1 kg/yr is associated with an annual decrease in SBP and DBP of 0.07 and 0.05mmHg, respectively, in hypertensive African-American women who were un-medicated. In fact, in the currently study we also showed that weight loss was significantly associated with reductions in both SBP ( $r=0.225$ ) and DBP ( $r=0.213$ ) (see Table 4.5). Moreover, a significant relationship was shown to exist when only analyzing data for individuals with  $SBP \geq 120$  mmHg between change in resting DBP and the change in weight when controlling for smoking (see Table 4.6). Thus, while cause and effect cannot be determined from these associations, these results appear to suggest that

weight loss does contribute to reductions in blood pressure in overweight and obese African-American women.

## **5.2 ASSOCIATION BETWEEN CHANGE IN MEASURES OF ADIPOSITY AND CHANGE IN BLOOD PRESSURE**

In this current investigation, we hypothesized that there would be a significant relationship between the change in adiposity, measured by BMI and waist circumference, and the change in resting blood pressure in African-American women. As shown in Table 4.5, there was a significant association between change in BMI and change in both SBP ( $r=0.230$ ) and DBP ( $r=0.225$ ), and conversely no association was observed for resting SBP when only analyzing data for individuals with a resting SBP  $\geq 120$  mmHg (see Table 4.6). Following this further, in those individuals an association was found for the change in BMI and the change in resting DBP after controlling for smoking (see Table 4.6). A similar pattern of differing results was observed for the associations between the change in waist circumference and change in both SBP and DBP (see Tables 4.5, 4.6, 4.7).

The results from the current study appear to be consistent with other studies in the literature that have reported on the associations between change in either BMI or waist circumference and change in resting blood pressure. For example, in a study of normo-tensive white women followed prospectively in the Aerobic Center Longitudinal Study, Barlow et al. [156] reported significant associations between change in BMI and both SBP ( $r=0.23$ ) and DBP( $r=0.21$ ), with comparable associations reported for change in waist circumference and change in SBP ( $r= 0.21$ ) and DBP ( $r= 0.19$ ). However, the results of the current study are not

consistent with the findings of Juhaeri et al. [155] who reported that change in both weight loss and fat distribution were not significantly associated with change in resting blood pressure in unmedicated, hypertensive African-American women across a period of 9 years.

The magnitude of the associations between change in either BMI or waist circumference report in this current study are also similar in magnitude to the cross-sectional associations reported between resting blood pressure and both BMI and waist circumference. Crane et al. [134] examined middle aged and elderly African-American women. Among those women with a BMI > 30kg/m<sup>2</sup>, BMI was significantly correlated with a higher SBP (r=.345) and DBP (r=.314). However, when including those women who were of normal weight and overweight higher waist circumference was associated with higher SBP (r=.370) and higher BMI was associated with higher DBP (r=.309).

We also examined the association between change in percent body fat and change in resting blood pressure, and did observe significant associations between these variables (see Tables 4.5, 4.6, 4.7). These results are similar to the findings reported by Kelley and Kelley [123], who reported no significant association between change in resting SBP and percent body fat in normo-tensive participants over 50 years of age. Moreover, these results are consistent with those found by Cornelissen and Fagard [126], Moreau et al. [133], and Kelley et al. [123] who reported that changes in measures of adiposity and blood pressure were not significantly correlated. These results may suggest that greater changes in adiposity are necessary to influence resting blood pressure or that other physiological mechanisms may influence changes in blood pressure, and this warrants further investigation.

### **5.3 ASSOCIATION BETWEEN CHANGE IN RESTING BLOOD PRESSURE AND CHANGE IN PHYSICAL ACTIVITY**

This study also examined the relationship between the change in resting blood pressure and the change in physical activity in African-American women. As shown in Table 4.5, there was a significant inverse association between the change in physical activity and the change in resting DBP, but not SBP. Both of the associations remained unchanged after controlling for smoking status. Furthermore, a significant association between change in both SBP and DBP and change in physical activity was observed when examining the women who had a baseline SBP  $\geq 120$  mmHg (see Table 4.6) and those with a baseline DBP  $\geq 80$  mmHg (see Table 4.7). Again, the associations remained statistically significant after controlling for smoking status.

There is scientific evidence to support a positive inverse relationship between physical activity and decreased blood pressure. For example, studies of aerobic exercise of normo-tensive adults have shown significant reductions in SBP and DBP of -2 and -1 mmHg, respectively [123]. Similar results were reported from a meta-analysis examining the effect of aerobic exercise on resting blood pressure in women [122].

Consistent with the results of the current study, research conducted with African-Americans also supports that physical activity can contribute to reductions in resting blood pressure. Brandon and Elliott-Lloyd [157] reported that a 16-week walking intervention, involving walking 3 miles per day on 3 days per week, decreased SBP by 5.7 mmHg and DBP by 3.0 mmHg in previously sedentary, obese African-American women. Following an 8 week exercise intervention, Staffileno et al. [136] reported a decrease in SBP of 6.4 mmHg in young African-American females with high normal and stage 1 blood pressure levels. Moreover, there

was a significant inverse correlation between change in SBP and duration of physical activity ( $r=-0.620$ ).

Conversely, Stephens et al. [135] reported that a 10-week aerobic training intervention does not significantly reduce blood pressure in pre-hypertensive, obese, African-American women. Similarly, Duncan, Gordon, and Scott [131] examined women (17% African-American) in a randomized walking trial for 6 months that rendered no significant change in blood pressure. These findings are consistent with other exercise studies that have not specifically focused on African-American women. For example, Lindheim et al. [158] reported that 6 months of exercise resulted in a significant decrease in SBP but not in DBP in postmenopausal women. Similarly, Duncan et al. [131] reported no effect from 6 months of walking on change in blood pressure in women (17% African-American). However, unlike the current study, these studies were not specifically intended to reduce body weight, which may have contributed to the difference in results in comparison to the current study.

Results from the RENEW Study [159], a one year lifestyle intervention in severely obese adults, which included 37% African-Americans, also contrast the findings in this investigation. The RENEW Study showed no added effect of physical activity to dietary restriction for reductions in both systolic and diastolic blood pressure. Following 6 months, dietary restriction resulted in reductions in SBP of 1.9 mmHg with the combination of dietary restriction and physical activity reducing blood pressure 3.4 mmHg, with no significant differences in these reductions in SBP. Dietary restriction also resulted in decreased DBP of 1.5 mmHg with the combination of dietary restriction and physical activity reducing DBP by 2.3 mmHg, which again was not significantly different between groups. However, these differences in results compared to the present study may be a result of the RENEW Study not excluding individuals

who were taking anti-hypertensive medication and that the RENEW Study only included those individuals with a baseline BMI  $\geq 35$  kg/m<sup>2</sup>.

The data from cross-sectional studies examining the association between physical activity and resting blood pressure appear to be equivocal. For example, Mora et al. [160] reported a significant reduction in the relative risk of hypertension within increasing levels of physical activity. However, Haapanen et al. [118] found no association between leisure-time physical activity and hypertension in women, and this is further supported by Young et al. [120] who reported a lack of an association between physical activity and hypertension in African-American women.

#### **5.4 ASSOCIATION BETWEEN CHANGE IN RESTING BLOOD PRESSURE AND CHANGE IN FITNESS**

In this study we also assessed the relationship between change in resting blood pressure and change in fitness. As shown in Table 4.5, there was a significant association between the change in fitness and the change in both resting SBP and DBP. These findings appear to be similar to those reported by Brandon and Elliot-Lloyd [157] in which a significant increase in fitness, expressed as maximal oxygen consumption, was accompanied by a significant decrease in resting SBP and DBP in African-American women in response to a 16-week brisk walking intervention. Moreover, results from a meta-analysis showed a significant inverse association between the change in DBP ( $r = -0.36$ ) and the change in fitness in adults with SBP  $> 120$  mmHg DBP  $< 80$  mmHg [123]. Further support of these results come from the Aerobics Center

Longitudinal Study, which showed a significant inverse relationship between the change in fitness and change in both SBP ( $r=-0.18$ ) and DBP ( $r=-0.17$ ) [156].

Within this study, when we examined only the women with a resting SBP  $\geq 120$  mmHg and women with a resting DBP  $\geq 80$  mmHg, the magnitude of the association between the change in fitness and the change in resting SBP and resting DBP was similar to what was reported by Cornelissen and Fagard [126]. The investigators found an association between the change in fitness and the change in both SBP ( $r=-0.24$ ,  $P<0.05$ ) and DBP ( $r=-0.40$ ,  $P<0.001$ ) in their meta-analysis examining the effect of endurance training on blood pressure. Blumenthal et al. [100] also reported a correlation between the change aerobic fitness and a change in SBP ( $r=-0.21$ ,  $P=.04$ ) and DBP ( $r=-0.27$ ,  $P=0.007$ ) in men and women with above normal blood pressures following a behavioral weight management program. Also, Kelley et al. [123] found a significant association between the change in fitness (maximal oxygen consumption) and change in DBP in a meta-analysis of the effect of walking interventions on blood pressure which was inclusive of some studies where subjects were on hypertensive medication.

Conversely, not all studies have demonstrated that improvement in fitness correspond to improvement in resting blood pressure. For example, Stephens et al. [135] reported a significant increase in fitness in pre-hypertensive African-American women following a 10-week exercise intervention. However, this intervention did not result in weight loss, nor did it result in reductions in resting blood pressure. This lack of an effect on resting blood pressure may be a result of the short duration of the study, the study sample that was pre-hypertension, or the lack of weight loss that was also observed as a result of this study. Thus, this may support the need for future research in this area to more clearly understand the relationship between fitness and resting blood pressure in African-American women.

## **5.5 MEDIATING EFFECT OF THE CHANGE IN PHYSICAL ACTIVITY OR FITNESS ON THE ASSOCIATION BETWEEN CHANGE IN MEASURES OF ADIPOSITY AND CHANGE IN RESTING BLOOD PRESSURE**

This study also examined the relationship between the change in measures of adiposity (body weight, BMI, waist circumference and percent body fat) and resting blood pressure was mediated by the change in physical activity. The relationship between change in resting SBP and change in waist circumference was partially mediated by change in physical activity (see Table 4.5), while the relationship between change in SBP and both weight and BMI is fully mediated. When only examining these relationships in the African-American women who had a baseline SBP  $\geq 120$  mmHg and after controlling for smoking status, physical activity fully mediated the relationship between waist circumference and SBP (see Table 4.6). Additionally, physical activity mediated the relationship between all the measures of adiposity (weight, BMI, and waist circumference) and resting DBP and adjusting for smoking had no effect. When only examining these relationships in African-American women who had a baseline  $\geq 80$  physical activity fully mediated the relationship between change in waist circumference and change in resting SBP whereas no significant relationships exist for changes in resting DBP and changes in any measure of adiposity.

Examination in this study of the relationship between the change in measures of adiposity (body weight, BMI, waist circumference and percent body fat) and the change in resting blood pressure was mediated by the change in fitness in African-American women. As shown in Table 4.5 the change in fitness completely mediated the relationship between the change in resting SBP and the change in weight and BMI. However, the change in fitness only partially mediated the relationship between the change in SBP and the change in waist circumference. Additionally,

the change in fitness completely mediated the relationship between the change in resting DBP and the change in all measures of adiposity (weight, BMI, waist circumference and percent body fat). When examining the women with a baseline resting SBP  $\geq 120$  mmHg and after controlling for smoking, the change in fitness fully mediated the relationship between the change in waist circumference and the change in SBP. Moreover, when examining those African-American women with a resting DBP  $> 80$  mmHg, the change in fitness fully mediated the relationship between the change in waist circumference and change in resting SBP before after controlling for smoking.

There is some evidence in the literature to support the finding that fitness can mediate the relationship between change in measures of adiposity and change in resting blood pressure. For example, data from prospective studies have shown that higher fitness is associated with lower odds of hypertension across varying categories of adiposity defined by BMI [156]. Moreover, cardiorespiratory fitness partially mediated the association between BMI and risk of hypertension in men and women in the longitudinal HYPGENE study [161].

Cross-section data reported by Wing et al. [162] from the Look AHEAD trial, which included women with type 2 diabetes mellitus, supports that both adiposity, measured by BMI, and fitness influence resting SBP blood pressure. Surprisingly, neither fitness nor adiposity appeared to significantly influence DBP in this population after controlling for age, race, smoking status, and diabetes duration [162]. The combined effect of cardiorespiratory fitness and waist circumference on resting blood pressure is also supported in a study of elderly Brazilian women with low to normal levels of blood pressure according to Krause, Hallage, Gama, Miculis, and Matuda [163]. Christou et al. [164], examined the independent association of

fitness and fatness with CVD risk factors in men, and reported that BMI continued to be associated with SBP after controlling for fitness.

Thus, these results appear to suggest that in some circumstances fitness can fully or partially the relationship between measures of adiposity and resting blood pressure. However, direct comparison to the results of the current study must be made with caution for a number of reasons. First, the current study examined these relationships within the context of a comprehensive behavioral weight loss intervention, whereas the majority of studies in the literature report on findings from cross-section studies or prospective non-intervention studies. Moreover, the current study examined these relationships specifically in overweight and obese African-American women, whereas, the studies available in the literature did not specifically report the results for African-American women.

## **5.6 EFFECTS OF EXERCISE ON POTENTIAL THAT INFLUENCES BLOOD PRESSURE.**

Aerobic training has been shown to influence central response of the cardiovascular system, and this may influence blood pressure. For example, stroke volume, blood volume, heart size, cardiac contractility, ventricular compliance and ventricular filling pressure are increased as a result of aerobic training while resting heart rate decreases [165]. These central adaptations play a significant role in the regulation of blood pressure [165].

While there is strong evidence to support the influence of exercise on blood pressure [50, 112, 122], there is still debate over the exact physiological processes by which exercise reduces blood pressure [166]. Neural and vascular mechanisms have been suggested by Pescatello et al.

[33] as potential explanations for reductions in blood pressure following endurance exercise. Arterial blood pressure is regulated by cardiac output and total peripheral resistance[167]. The primary mechanism influencing the reduction in resting blood is the reduction in total peripheral resistance [33]. Total peripheral resistance is reduced because of increases in the diameter of blood vessels and greater arterial compliance which result from aerobic training [33]. Moreover, exercise has been shown to increase sympathetic nerve activity, norepinephrine, and nitric oxide, which augment vasodilation and resulted in the lowering of blood pressure [33]. Improved endothelial function and vascular remodeling may also be result from aerobic training and contribute to reducing both total peripheral resistance and resting blood pressure [33]. Finally, there is some evidence which suggests genetics influence the relationship between exercise training and resting blood pressure [168]; however, more research is needed in this area [33].

## **5.7 LIMITATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH**

Five weight loss studies were combined and data retrospectively analyzed to examine the relationship between both blood pressure and body mass index, and physical activity in overweight and obese African-American women. The following points should be considered before generalizing the results to other groups.

- 1) This investigation was a secondary analysis of data obtained from 0 to 6 months within the context of behavioral weight loss interventions. Thus, these studies from which these data are derived were not specifically designed to examine the aims of this current study, and this may influence the findings and conclusions. Thus, replication of these findings is needed from studies that *a-priori* are designed appropriately to answer these important clinical research questions. In addition, while intervention components appear to be similar it is possible that some differences exist between the interventions which may have affected the results of this current investigation.

- 2) The changes in body fat and blood pressure as a result of changes in estrogen should be considered when examining the relationship between women and blood pressure. In this investigation, we were unable to control for menopausal status; therefore, future studies should consider the influence of menopausal status on measures of adiposity and blood pressure in women.
- 3) Data for sodium intake was unavailable to include in this study. It has been shown that a decreased sodium intake significantly influence blood pressure in African-Americans [68]. Thus future investigations should include measures of sodium intake and other nutritional variables when examining the influence of adiposity, activity, and fitness on blood pressure in African-American women.
- 4) In this investigation the subjects used were healthy African-American women, between 18 and 55 with a BMI of 25 to  $<40 \text{ kg/m}^2$  who were not using hypertensive medications and as a result, the findings of this study will only be generalizable to individuals who are similar to the subjects who participated in this study. However, because we found an effect in individuals who were non-medicated and non-hypertensive, this limitation may also be considered a strengths of this investigation. Future studies in African-American women should include those with a BMI  $\geq 40$ , those using hypertensive medications, and those who are diabetic or who have other chronic diseases to determine if these findings are robust across these population groups.
- 5) This study focused primarily on African-American women, which limits generalizability to men and other ethnic/racial groups. Moreover, this study did not directly compare African-American women to other population groups. Therefore, future studies should be expanded to include men and individuals from other ethnic/racial groups to determine if the results differ between different race-sex groups.
- 6) Physical activity was self-reported for this study. Self-reported measures of physical activity are known to be imprecise; therefore, future research should also include objective measures of physical activity for more accurate accounts of exercise frequency, intensity, and duration.
- 7) Cardiorespiratory fitness was assessed using a submaximal exercise protocol with fitness. While this methodology has been shown to be sensitive to determining change in fitness across time, future studies should consider the use of a maximal exercise test that also measures expired gases to express fitness.
- 8) This study used bioelectrical impedance analysis to measure body composition, and this may have influenced the findings in this study. Future studies should consider the use of other techniques to measure body composition such as dual-energy x-ray absorptiometry (DXA) or magnetic resonance imaging (MRI).
- 9) Waist circumference was used as a measurement of abdominal adiposity. However, waist circumference does not provide separate measures of visceral or subcutaneous abdominal adiposity. Therefore, future studies should consider including MRI or CT techniques to provide direct measures of visceral and subcutaneous adiposity.

**10)** The data used in this analysis was for changes manifested over a six-month period, and significant associations were demonstrated between change in measures of adiposity and change in blood pressure. Future research should examine whether those relationship remain at different time points exceeding six months i.e. 12 or 18 months. In addition, ceilings in levels of physical activity and cardiorespiratory fitness levels may be identified where increases in those variables are found to have no additional effect on blood pressure regulation.

## **5.8 SUMMARY**

We have examined the relationship between changes in measures of adiposity on changes in resting blood pressure in African-American women. In addition, we examined the mediation effect of changes in both physical activity and cardiorespiratory fitness on that relationship. This study demonstrated that decreases in measures of adiposity influence changes in blood pressure in obese African-American women. This study also supports the mediation model we hypothesized and demonstrates the importance of physical activity and fitness in lowering blood pressure in African-American obese women who undertake dietary change for weight loss. African-American women are among those with the highest rates of obesity and hypertension and lowest physical activity in the United States. While in need of replication, the findings from this study support the need for physical activity interventions that increase cardiorespiratory fitness within the context of weight loss interventions in African-American women.

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