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The effects of aerobic exercise in hypertensive adults: A meta-analytic review

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The Effects of Aerobic Exercise in Hypertensive Adults: A Meta-Analytic Review

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The Effects of Aerobic Exercise in Hypertensive Adults: A Meta-Analytic Review

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ABSTRACT

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George A. Kelley, Jr.

The purpose of this study was to examine the effects of aerobic exercise on resting systolic and diastolic blood pressure in hypertensive adults. Thirty-two longitudinal journal training studies, published in English and conducted over the past 25 years, were analyzed using the meta-analytic technique.

Within groups, t-distribution analysis of effect size changes revealed significant differences ($p < .05$) for resting systolic and diastolic blood pressure across all exercise groups and categories. Between groups, one-way analysis of variance revealed no significant difference ($p < .05$) in aerobic exercise-induced effect size blood pressure changes among categories. None of the changes were significant for the control groups.

Significant relationships (r, $p < .05$) existed between aerobic exercise-induced effect size changes on resting blood pressure and changes in body weight and percent fat (systolic only) and initial percent fat levels (systolic and diastolic). Relationships for age, initial weight, or initial blood pressure levels were not significant. In addition, no significant relationships existed between characteristics of training programs and aerobic exercise-related changes in resting blood pressure.

It was concluded that aerobic exercise reduced resting systolic and diastolic blood pressure across all categories of hypertensive adults. In addition, the magnitude of aerobic exercise-induced reductions on resting blood pressure was associated with smaller changes in body weight and higher initial levels of percent fat (systolic only) and larger decreases in percent fat (systolic and diastolic).

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CHAPTER 1

Introduction

Arterial hypertension affects approximately 60 million American adults today (Frohlich, 1989). Essential, or primary, hypertension which has no identifiable, specific cause accounts for approximately 90 percent of hypertensive cases (Kilcoyne, 1980). According to the American Heart Association (1989), high blood pressure contributes to heart failure and atherosclerosis. It is listed along with smoking, high blood cholesterol, and diabetes as one of the four most powerful predictors for coronary vascular disease (Whitney & Sizer, 1989).

In addition to the effect on an individual's health, the high costs associated with the detection, treatment, and management of hypertension have made this a significant socioeconomic issue (Frohlich, 1979; United States Public Health Services Hospitals Cooperative Study Group, 1972). According to Frohlich (1989), the treatment of hypertension includes expensive pharmacological therapies, such as diuretics, potassium-sparing agents, beta-adrenergic blocking agents, adrenergic inhibiting compounds, vasodilators, angiotensin-converting enzyme inhibitors, and calcium antagonists. Nonpharmacological and more inexpensive methods for the treatment of hypertension include weight reduction, moderation of alcohol intake, sodium restriction, smoking cessation, stress reduction, and aerobic exercise.

Because of the potential problems associated with the pharmacological treatment of hypertension (side effects, lack of patient compliance, and cost), most hypertension specialists today first recommend nonpharmacological approaches to prevent and treat high blood pressure (Tifft, 1990). If nonpharmacological therapy fails to lower blood pressure appropriately, then pharmacological therapy is used in a step-care fashion (Joint National Committee on Detection, Evaluation, and Treatment of High Blood Pressure, 1988).

While aerobic exercise is commonly recommended as a nonpharmacological therapy in the reduction of hypertension today (Joint National Committee on Detection, Evaluation, and Treatment of High Blood Pressure, 1988; Working Group on Management of Patients with Hypertension and High Blood Cholesterol, 1991), its role as a nonpharmacological treatment and the potential confounding variables associated with its use are still an area of considerable debate. Several reviews (Gordon, Scott, Wilkinson, Duncan, & Blair, 1990; McMahon & Palmer, 1985; Tipton, 1984, 1991) concluded that aerobic exercise reduced resting blood pressure in hypertensive adults. However, none of the reviews reached mutual agreement on either the magnitude of change in resting blood pressure or the effects of potential confounding variables on these exercise-induced changes. In contrast to these reviews, Seals and Hagberg (1984) concluded that insufficient evidence existed to recommend aerobic exercise as a nonpharmacological therapy for the reduction of resting blood pressure in hypertensive adults.

Thus, the purposes of this study were: (1) to examine, through meta-analytic techniques, the effects of aerobic exercise on resting systolic and diastolic blood pressure in hypertensive adults and (2) to provide recommendations to undergraduate exercise physiology instructors for teaching a module on the role of aerobic exercise as a potential treatment in the reduction of resting systolic and diastolic blood pressure in hypertensive adults.

Hypotheses

For the purpose of this study, the following hypotheses were tested:

1. Aerobic exercise will not affect resting systolic blood pressure in hypertensive adults.

2. Aerobic exercise will not affect resting diastolic blood pressure in hypertensive adults.

3. Initial blood pressure levels will not be associated with aerobic exercise-induced changes in resting systolic blood pressure in hypertensive adults.

4. Initial blood pressure levels will not be associated with aerobic exercise-induced changes in resting diastolic blood pressure in hypertensive adults.

5. Age will not be associated with aerobic exercise-induced changes in resting systolic blood pressure in hypertensive adults.

6. Age will not be associated with aerobic exercise-induced changes in resting diastolic blood pressure in hypertensive adults.

7. Body weight will not be associated with aerobic exercise-induced changes in resting systolic blood pressure in hypertensive adults.

8. Body weight will not be associated with aerobic exercise-induced changes in resting diastolic blood pressure in hypertensive adults.

9. Body fat will not be associated with aerobic exercise-induced changes in resting systolic blood pressure in hypertensive adults.

10. Body fat will not be associated with aerobic exercise-induced changes in resting diastolic blood pressure in hypertensive adults.

11. Length of training will not be associated with aerobic exercise-induced changes in resting systolic blood pressure in hypertensive adults.

12. Length of training will not be associated with aerobic exercise-induced changes in resting diastolic blood pressure in hypertensive adults.

13. Frequency of training will not be associated with aerobic exercise-induced changes in resting systolic blood pressure in hypertensive adults.

14. Frequency of training will not be associated with aerobic exercise-induced changes in resting diastolic blood pressure in hypertensive adults.

15. Intensity of training will not be associated with aerobic exercise-induced changes in resting systolic blood pressure in hypertensive adults.

16. Intensity of training will not be associated with aerobic exercise-induced changes in resting diastolic blood pressure in hypertensive adults.

17. Duration of training will not be associated with aerobic exercise-induced changes in resting systolic blood pressure in hypertensive adults.

18. Duration of training will not be associated with aerobic exercise-induced changes in resting diastolic blood pressure in hypertensive adults.

Delimitations

This study was limited to library research aided by computer searches (ERIC, Medline, and Sport) at Middle Tennessee State University and Vanderbilt University. Longitudinal studies chosen for evaluation were limited to those published in journals over the past 25 years (1966-1991) in which lower extremity aerobic exercise was the primary mode of training in hypertensive adults.

Definition of Terms

The following definitions were given for terms used in this study.

1. Adult--any human who is 18 years of age or older.

2. Aerobic exercise--exercises that utilize large muscle groups in slow, continuous, rhythmical motion.

3. Effect size--unit of analysis in meta-analysis. The degree to which the null hypothesis is false.

4. Hypertension--high blood pressure persistently exceeding a systolic pressure of 140 millimeters of mercury (mmHg) and/or a diastolic blood pressure of 90 mmHg.

5. Meta-analysis--data analysis applied to quantitative summaries of individual experiments.

6. Post-exercise--cessation of an exercise program at least 24 hours after the last session has been completed.

7. Primary hypertension--high blood pressure which has no one known cause.

8. Secondary hypertension--high blood pressure caused by diseases of the kidneys, lungs, glands, and vessels.

Significance of the Study

Traditional reviews dealing with the effects of aerobic exercise on resting systolic and diastolic blood pressure in hypertensive adults (Gordon et al., 1990, McMahon & Palmer, 1985; Seals & Hagberg, 1984; Tipton, 1984, 1991) have relied on subjective and possibly biased conclusions based on the traditional approach in which studies were chronologically listed and described by the reviewers. A need exists to quantitatively evaluate previous studies for the purpose of providing more objective evidence regarding the efficacy of aerobic exercise in the prevention and treatment of hypertension. To date, no study of this nature has appeared in manuscript form in primary research journals. Meta-analysis provides more "rational" understanding of the efficacy of aerobic exercise as a nonpharmacological therapy in the treatment of resting systolic and diastolic blood pressure in hypertensive adults. Chalmer (cited in Mann, 1990) recently stated that "meta-analysis is going to revolutionize how the sciences, especially medicine, handle data, and it's going to be the way many arguments will be ended" (p. 478).

The results of meta-analysis will be used to make recommendations for the teaching of "appropriate" and more detailed information on hypertension. There exists a great need in the field of exercise physiology to enhance understanding of hypertension. Knowledge concerning the effects of aerobic exercise in hypertensives is critical for all elementary and secondary school physical education teachers. Cognition is also essential for professionals employed in fitness and wellness occupations within hospital-based cardiac rehabilitation programs, YMCA's, YWCA's, corporate fitness centers, and senior citizens centers, to name a few. Behaviors which are learned early in life are retained later in life. Therefore, elementary and secondary school teachers need to be equipped with the knowledge necessary for educating students on the benefits of aerobic exercise in the prevention and treatment of high blood pressure. For those individuals employed in fitness and wellness occupations, a thorough understanding of the role of aerobic exercise in the prevention and treatment of adult hypertension is also necessary. According to the American Heart Association (1989), high blood pressure: (1) claims a significant number of American lives each year (30,960 in 1988); (2) is a major risk factor in heart attacks; and (3) is the major risk factor in stroke. Thus, it is obvious that fitness and wellness professionals need to be provided with up-to-date knowledge on the benefits of aerobic exercise in dealing with this disease. Acquisition of this knowledge will allow the opportunity to educate the population. Unfortunately, current exercise physiology textbooks provide little information on this topic. For example, Fox, Bowers, and Foss (1989) in their textbook provide little more than a definition of high blood pressure and a statement that aerobic exercise reduces resting blood pressure in humans. They provide no information on the effects of aerobic exercise in hypertensive adults. Powers and Howley (1990) in their textbook provide even less information. They simply define hypertension. In addition, deVries (1986), devotes no more than two paragraphs of his textbook to the topic, while Noble (1986) devotes only one. Thus, there is an obvious need to enhance our understanding of this topic so that we may equip our future professionals with the knowledge necessary for educating others.

CHAPTER 2

Review of Related Literature

The review of literature is presented in four sections. The first section deals with a brief history of hypertension. The second section describes human training studies which were published in journals and conducted during the last 25 years. This section is further categorized by studies which found: (1) decreases in both resting systolic and diastolic blood pressure, (2) decreases in resting systolic or diastolic blood pressure, (3) no decreases in both resting systolic and diastolic blood pressure, and (4) differences in resting blood pressure partitioned by selected variables. The third section summarizes the results of these findings. The final section describes the results of previous reviews on this topic.

Historical Overview

The history of hypertension may have begun with the work of Samuel Schaarschmidt in Berlin (Folkow, 1982) approximately a century after William Harvey's observations in 1628 on the force with which blood flowed from a severed artery (Pickering, 1964). This was approximately 10 years after Stephen Hales of England, who in 1733 proved that flowing blood exerted a force on the walls of vessels (Ruskin, 1956). Schaarschmidt observed that some humans' circulation was in an extremely excited state and concluded that it was the result of a spastic constriction of the vascular bed. His recommendations for nonpharmacological therapy included adjustments in lifestyle in order to reduce excitement and pharmacological treatment in the form of sedatives and nitrites. The latter is known today to be a vasodilator. Schaarschmidt's subjective observations were actually dealing with the disease that we currently know today as primary hypertension (Folkow, 1982).

The work of London's Richard Bright, a physician-pathologist, is considered by others to be the beginning of the history of hypertension (Pickering, 1964). Bright (1827, 1836) reported information concerning patients he had performed autopsies on over a period of 12 years. In 1827, he reported that all patients with coagulated urine who died of dropsy had some type of kidney abnormality. Further, in 1836, he reported on 100 cases of individuals with excessive albumin in the urine and observed structural changes of the heart, most notably left ventricular hypertrophy. Along with this hypertrophy, he observed an increase in the force of the pulse. Bright hypothesized that these alterations were the result of blood abnormalities which either: (1) caused an anomalous stimulus to the heart directly or (2) affected the circulation in the arterioles and capillaries. According to Bright, this condition resulted in greater force required to supply blood to distant vessels. The disease of the kidneys characterized by albuminuria and a heightened blood pressure became known as Bright's disease and was synonymous with the term nephritis for many years (Folkow, 1982). Today, high blood pressure from kidney disease (kidney cancer, kidney stones) is classified as a form of secondary hypertension, specifically, renal hypertension (Glanze, Anderson, & Anderson, 1985).

Johnson (1868) of Kings College Hospital in London followed up on the work of Richard Bright (1827, 1836) and found that the small and large arteries in the kidneys and the rest of the body were narrowed in patients with Bright's disease. Johnson hypothesized incorrectly that the thickening of the arteries was the consequence of a muscular hypertrophy of the arterial walls. He initially hypothesized in 1868 that this muscular hypertrophy was the result of vascular spasm, but later in 1873 attributed this physiological occurrence to a retention of urine as a consequence of renal degeneration (Ruskin, 1956). Johnson concluded that the arteries of the body, like the hypertrophied left ventricle, had to work more forcefully in order to pump blood through the contracted kidneys of individuals with Bright's disease.

By 1872, Ludwig Traube (cited in Pickering, 1964), like Bright (1827, 1836), found a relationship between left ventricular hypertrophy and kidney disease. Traube attributed this left ventricular hypertrophy and raised arterial pressure solely to alterations in the kidney.

Gull and Sutton (1872) of Guy's Hospital in London and London Hospital, respectively, found, like Johnson (1868), a narrowing of the small arteries of the body. However, the researchers offered an alternative solution as to the nature of this alteration. The investigators surmised, albeit incorrectly, that the narrowing of these arteries was not the result of muscular hypertrophy of the arterial walls, but a "hyaline fibroid" formation in these vessels. The pair concluded that Bright's disease was the result of a narrowing of the small arteries and capillaries of the body, which in turn caused left ventricular hypertrophy and contracted kidneys.

Around the same period, Fred A. Mahomed (1872), also of Guy's Hospital in London, became the first person to estimate arterial pressure with an instrument known as a sphygmograph. Using the sphygmograph, he proved that arteriocapillary fibrosis could occur without renal involvement. He wrote:

> The observations I bring before you are briefly these: that previous to the commencement of any kidney change, or to the appearance of albumin in the urine, the first condition observable is high tension in the arterial system. The series of cases I especially draw your attention this evening are all of one type. Their characteristic features are these: they all occur in patients recovering from scarlet fever. (Mahomed, 1872, p. 62)

Mahomed (1872) also noted that high arterial pressure was present in individuals with cirrhosis of the kidneys and eclampsia. In addition, Mahomed (1879) discovered that individuals who were in apparently good health also demonstrated a high arterial pressure. He termed this condition as chronic Bright's disease without albuminuria. Thus, Mahomed was the first person to recognize primary, or essential, hypertension. His work was further supported by Huchard (1889) of Paris, who used the term presclerosis to describe this condition. Basch (cited in Pickering, 1964), who developed a more improved instrument for measuring arterial pressure (sphygmomanometer), found heightened arterial pressures in some patients in 1893. He attributed these elevated pressures to arteriosclerosis and used the term latent arteriosclerosis to describe this condition.

In addition, Albutt (1895) of Cambridge, England examined five patients with raised arterial pressures without the presence of albuminuria and concluded that individuals with elevated arterial pressures needed to be categorized as having either: (1) Bright's disease or (2) hyperpiesis, a term used to describe individuals in whom blood pressure started to rise at middle age. Thus, Albutt, like Mahomed (1879), Huchard (1889), and Basch (cited in Pickering, 1964), discovered that hypertension occurred without renal disease. Frank (cited in Pickering, 1964) in 1911 termed this elevation in arterial pressure with no known cause as essentielle hypertonie or essential hypertension--the same term that is used today.

In Germany, Volhard and Fahr (cited in Pickering, 1964), as a result of their clinical studies in 1914, devised a classification system for the various forms of hypertensive disorders. They divided these ailments into: (1) degenerative diseases, (2) inflammatory diseases, and (3) arteriosclerotic diseases. The arteriosclerotic diseases were further divided into those which were characterized by hypertension of the benign or malignant type. Later, they described these two forms of hypertension as red (benign) and white (malignant). They felt that red hypertension (uncomplicated essential or primary hypertension) was the result of a diminished elasticity of the arteries and arterioles, a condition attributed to age and heredity. This condition was void of any kidney abnormalities. In contrast, pale or white hypertension, according to Volhard and Fahr, was distinguished by retinitis, albuminuria, extremely high blood pressure, and kidney problems. He hypothesized that pale hypertension was the result of a renal pressor substance which was released due to poor blood supply to the kidney.

Knowledge concerning hypertension was furthered by the work of Derow and Altschule (1935) who demonstrated that malignant hypertension occurred: (1) without any prior hypertension, (2) as the end phase of essential or primary hypertension, or (3) as the end phase of a variety of anomalous conditions distinguished by hypertension secondary to such diseases as glomerular nephritis, adrenal tumor, and chronic lead poisoning. Goldblatt (1938), having previously developed a method for examining renal hypertension by clamping the renal arteries of dogs, showed that tissue death to the arteries in animals occurred when hypertension was induced by narrowing these arteries.

Additionally, Wilson and Byrom (1941) found that clamping one renal artery in rats produced an exaggerated hypertension and arterial and glomerular tissue death in the kidney. This was similar to what occurred as a result of malignant hypertension.

As a result of Wilson and Byrom's (1941) work, Pickering (1942) hypothesized that different intensities distinguished benign and malignant forms of hypertension. Later he found support for this hypothesis. This assumption has been further proven as a result of the use of hypotensive drugs.

Today, it is generally believed that most forms of hypertension are the result of an increase in total peripheral resistance (Frohlich, 1982). In addition, hypertension is now classified as either primary or essential and secondary. Secondary hypertension is related to diseases of the lungs, kidneys, glands, and vessels. This type of identifiable hypertension accounts for approximately 10 percent of the hypertensive population (Glanze et al., 1985). In contrast, primary, or essential, hypertension has no one known cause and accounts for approximately 90 percent of hypertensive cases (Kilcoyne, 1980). Essential or primary hypertension is symptomless until the symptoms of its complications develop. Factors which have been attributed to this form of hypertension include heredity, environment, stress, race, smoking, overweight, birth control pills, sedentary lifestyle, tobacco, aging, and/or high sodium intake (Glanze et al., 1985). An individual is classified as being hypertensive if he or she demonstrates a systolic blood pressure of 140 mmHg or greater and/or a diastolic blood pressure of 90 mmHg or greater (American Heart Association, 1989). According to the American College of Sports Medicine (1991), hypertensives have been further categorized as systolic/diastolic mild (140-149/90-95 mmHg), moderate (150-159/96-100 mmHg), or severe ($\geq$160/100 mmHg).

The treatment of hypertension today includes both pharmacological and nonpharmacological therapy. Expensive pharmacological treatment includes the use of thiazide, diuretics, beta-blockers, methyldopa, guanethidine, and a combination of others (Tifft, 1990). According to Frohlich (1989), inexpensive nonpharmacological therapy includes a reduction in weight, moderate use of alcohol, a decrease in sodium intake, smoking cessation, stress reduction, and aerobic exercise.

Aerobic Exercise and Hypertension

The role of aerobic exercise as a nonpharmacological therapy in the treatment of adult hypertension today is still an area of controversy. There is a lack of agreement regarding the magnitude and direction of change, as well as the effect of potentially confounding variables.

Longitudinal Studies Finding Reductions in Resting Systolic and Diastolic Blood Pressure

Rudd and Day (1967) examined the effects of 22 weeks of physical training on 19 hypertensive males. The subjects trained at a combination of activities for 60 minutes per session. The results of the study demonstrated statistically significant decreases in both resting systolic and diastolic blood pressure. Systolic pressure declined by M = 22 mmHg (from M = 155, SD = 12 to M = 133, SD = 12 mmHg), and diastolic pressure dropped M = 10 mmHg (from M = 95, SD = 10 to M = 85, SD = 10 mmHg). The authors concluded that physical training reduced resting blood pressure in hypertensive patients. Unfortunately, no data were reported on the frequency or intensity of the exercise sessions. In addition, the authors did not report any data on body weight or percent fat for the participants. Furthermore, no hypertensive control group was included. Finally, this was the only study reviewed in which blood pressure was measured indirectly from tracings of a Heartometer, a blood pressure device which was questioned by the scientific community.

Another study which found decreases in resting blood pressure was conducted by Boyer and Kasch (1970). Twenty-three middle-aged hypertensive men cycled on an ergometer two times per week for 40-50 minutes at an intensity equivalent to 70 percent of their maximum heart rate. The training paradigm lasted 24 weeks. The authors reported training significantly decreased both resting systolic and diastolic blood pressure (M = 159 vs. M = 146 mmHg, M = 105 vs. M = 93 mmHg). The investigators concluded that hypertensive patients could be effectively trained without undue risk if their condition was monitored during exercise and if specific signs and symptoms were noted during each exercise session. Unfortunately, no hypertensive control group or standard deviations were reported.

One of the two studies which used both indirect and direct blood pressure measurements was conducted by Hanson and Nedde (1970). The investigators examined the effects of physical training on two different categories of hypertensive males, aged 30 to 54, over a period of 28 weeks. The hypertensives were divided into two groups, those with moderate hypertension (N = 5) and those with severe hypertension (N = 8). The subjects trained utilizing a combination of activities (distance running, squash, paddle-ball, basketball, flexibility exercises, isometric-isotonic maneuvers) three times per week for 60 minutes per session. Post-exercise results, measured invasively, showed statistically significant decreases in resting systolic and diastolic blood pressure for both groups. The moderately hypertensive group lowered resting systolic blood pressure ($\underline{M}$ = 15 mmHg, from $\underline{M}$ = 150 to $\underline{M}$ = 135 mmHg) and resting diastolic blood pressure ($\underline{M}$ = 12 mmHg, from $\underline{M}$ = 87 to $\underline{M}$ = 75 mmHg). The severely hypertensive group decreased resting systolic pressure ($\underline{M}$ = 33 mmHg, from $\underline{M}$ = 170 to $\underline{M}$ = 137 mmHg) and diastolic pressure ($\underline{M}$ = 13 mmHg, from $\underline{M}$ = 90 to $\underline{M}$ = 77 mmHg). Taken as a group, indirect measurements of blood pressure showed a decline from $\underline{M}$ = 179 to $\underline{M}$ = 137 mmHg for resting systolic pressure and $\underline{M}$ = 90, $\underline{M}$ = 77 mmHg for resting diastolic pressure. Direct measurements of blood pressure demonstrated a reduction of $\underline{M}$ = 150 to $\underline{M}$ = 134 mmHg for resting systolic pressure and $\underline{M}$ = 86 to $\underline{M}$ = 75 mmHg for resting diastolic pressure. The researchers concluded that physical training lowered resting blood pressure in moderate and severely hypertensive males. No data were provided for body weight, percent fat, or intensity of training for the subjects. In addition, no hypertensive control groups were included in the study, and no standard deviations were reported for these data.

A study which used a large number of subjects and a hypertensive control group was conducted by deVries (1970).

Sixty-six hypertensive men took part in a training program which consisted of walking and jogging over a seven-week period. The participants trained three times per week at a training intensity of 145 heart-rate beats per minute. The duration of each session ranged from 30 to 40 minutes. Results demonstrated a statistically significant decrease in both resting systolic ($\underline{M}$ = 140, $\underline{SD}$ = 21 vs. $\underline{M}$ = 136, $\underline{SD}$ = 19 mmHg) and diastolic ($\underline{M}$ = 76, $\underline{SD}$ = 11 vs. $\underline{M}$ = 73, $\underline{SD}$ = 9 mmHg) blood pressure as a result of the training program. Small reductions were noted for body weight and body fat ($\underline{M}$ = 2 kg, $\underline{M}$ = 2 percent). None of the changes were significant for the hypertensive control group. The author concluded that an aerobic training program was both safe and effective in the reduction of resting blood pressure in hypertensive men.

The effect of aerobic exercise on resting blood pressure in hypertensives was also examined by Nelson, Jennings, Esler, and Korner (1986). Using a Latin square design, 13 untreated male and female patients (age, $\underline{M}$ = 44 years) with essential hypertension participated in four-week periods of: (1) inactivity, (2) 45 minutes of bicycling at 60 to 70 percent of maximum work capacity three times per week, and (3) 45 minutes of bicycling at 60 to 70 percent of maximal work capacity seven times per week. Supine resting blood pressure, measured by auscultatory cuff method, was significantly reduced after all periods.

Resting systolic and diastolic blood pressure was reduced by 5/3 mmHg after the sedentary period, 11/9 mmHg after exercising three times per week, and 16/11 mmHg after exercising seven times per week. The authors concluded that moderate, regular exercise lowered blood pressure and seemed to be an important nonpharmacological method of treating hypertension. No data on percent body fat were provided.

Wilmore, Royce, Girandola, Katch, and Katch (1970), using a small number of hypertensive subjects, examined the effects of jogging over a 10-week period in males, aged 45 to 59. Seven subjects trained three times per week for 12 to 24 minutes per session at seven and one-half miles per hour. The results of the study revealed a significant post-exercise reduction in systolic and diastolic blood pressure. Systolic blood pressure declined by M = 15 mmHg (from M = 140, SD = 14 to M = 125, SD = 17 mmHg), while diastolic blood pressure dropped 7 mmHg (from M = 81, SD = 9 to M = 74, SD = 9 mmHg). There was a small decrease in body weight (M = 1 kg). The investigators concluded that jogging reduced resting blood pressure in hypertensive individuals. Unfortunately, no data were provided on percent fat, and no hypertensive control group was included in their study.

Another study which found decreases in resting blood pressure was conducted by Choquette and Ferguson (1973). The researchers examined the effects of aerobic exercise on 37 "borderline" hypertensive males over a period of 24 weeks. The subjects trained seven days per week for a duration of 10-60 minutes, utilizing a combination of activities. The investigators did not describe the intensity at which the subjects trained during each session. The results indicated a statistically significant reduction in both resting systolic and diastolic blood pressure as a result of the training program (M = 136, SD = 13 vs. M = 122, SD = 14 mmHg; M = 90, SD = 7 vs. M = 82, SD = 10 mmHg). There were no changes in body weight. The authors concluded that exercise reduced resting systolic and diastolic blood pressure in borderline hypertensives. No information was provided on the percent fat levels of the subjects, and no hypertensive control group was included.

The only study which used females exclusively as subjects was conducted by Roman, Camuzzi, Villalon, and Klenner (1981). Using 24 female subjects, the researchers investigated the effects of a 12-week physical training program on arterial hypertension. The subjects performed a combination of aerobic activities three times per week for 30 minutes per session at a heart rate equivalent to 70 percent of maximum. Results of the study demonstrated statistically significant decreases of M = 22 mmHg (M = 182, SD = 16 vs. M = 161, SD = 18 mmHg) in resting systolic pressure and M = 16 mmHg (M = 113, SD = 10 vs. M = 94, SD = 11 mmHg) in resting diastolic pressure. In addition, when exercise training was stopped, resting blood pressure increased to M = 179, M = 113 mmHg for resting systolic and diastolic blood pressure, respectively. The investigators concluded that physical training reduced resting blood pressure in females with arterial hypertension. No data were provided on body weight or percent fat, and no hypertensive control group was included in the study.

Additionally, Cade et al. (1984), using a large number (N = 105) of patients, investigated the effects of aerobic exercise on a large number of hypertensive males and females. Contrary to previous studies, the subjects were divided into two groups: one group (N = 58) which had not been taking any hypertensive drug medication and another group (N = 47) which had been receiving pharmacological therapy. The subjects trained by walking two miles per session for a duration of 40 minutes per session. The frequency of exercise was three times per week for a period of 12 weeks. The specific intensity of the training was not reported. For the 58 patients who did not receive hypertensive drug medication prior to the training program, statistically significant decreases of M = 15 mmHg and M = 12 mmHg were observed for resting systolic and diastolic blood pressure, respectively. The 47 patients who received hypertensive drug therapy prior to the exercise program also significantly reduced resting systolic (M = 31 mmHg) and diastolic (M = 22 mmHg) blood pressure. The average reduction in body fat was 2 percent. Additionally, after three months of inactivity, resting systolic and diastolic blood pressure increased by M = 17 and M = 20 mmHg, respectively. As with previous investigations, the authors concluded that hypertensive patients who were physically and emotionally able to exercise lowered resting blood pressure through aerobic activity. Insufficient data were given on the body weight of the subjects, and no hypertensive control group was identified. In addition, results according to gender were not reported.

Kiyonaga, Arakawa, Tanaka, and Shindo (1985) also found decreases in high blood pressure as a result of aerobic exercise. This 20-week study used both males and females (N = 9) with essential hypertension. The subjects participated in cycle ergometry at an intensity of 50 percent of their maximum oxygen consumption three days per week, 60 minutes per session. Results of the study showed a statistically significant reduction in both systolic (M = 157, SD = 4 vs. M = 139, SD = 5 mmHg) and diastolic (M = 104, SD = 3 vs. M = 90, SD = 3 mmHg) blood pressure at rest. Body weight decreased by M = 2 kg. The investigators concluded that aerobic exercise reduced resting blood pressure levels in essential hypertensives. No hypertensive control group, percent fat levels, or gender data were reported.

One study which partitioned results according to responders and nonresponders was conducted by Kinoshita et al. (1988). The researchers examined the effects of a 10-week exercise program on 21 males and females, aged 32 to 60, with essential hypertension. Subjects exercised on a cycle ergometer three times per week for a duration of 70 minutes per session. The training intensity was set at 40 to 60 percent of maximum oxygen consumption. The overall results demonstrated a statistically significant reduction in both systolic and diastolic blood pressure at rest (M = 154, SD = 3 vs. M = 141, SD = 3 mmHg; M = 100, SD = 2 vs. M = 93, SD = 3 mmHg). When data were partitioned according to responders and nonresponders, 12 of the subjects (responders) demonstrated significant decreases of M = 19 and M = 12 mmHg for resting systolic and diastolic blood pressure. The nonresponders (N = 9) demonstrated insignificant reductions of M = 7 and M = 1 mmHg systolic and diastolic blood pressure, respectively. No significant changes in body weight were noted. The investigators concluded that exercise lowered blood pressure in mild hypertensives and that responders had a higher cardiac index and serum sodium:potassium ratio and lower total peripheral resistance. No information was provided on percent fat levels of the participants, and no hypertensive control group was included.

One of the few training studies in which separate data were reported according to gender was conducted by Tanabe et al. (1988). Thirteen males and 11 females performed cycle ergometry over a 10-week period. The subjects were divided by gender into two groups, both training three days per week for 70 minutes per session at 50 percent of their maximum oxygen consumption. Post-exercise results revealed statistically significant decreases in resting systolic blood pressure for both groups (M = 147, SD = 15 vs. M = 139, SD = 18 mmHg for males; M = 156, SD = 15 vs. M = 139, SD = 15 mmHg for females). In addition, a statistically significant reduction was observed in post-exercise resting diastolic blood pressure for both groups (M = 99, SD = 9 vs. M = 95, SD = 15 mmHg for males; M = 98, SD = 9 vs. M = 91, SD = 12 mmHg for females). No changes in body weight for either of the groups were noted. The researchers concluded that aerobic exercise decreased resting blood pressure in both male and female hypertensives. No control group was included in this investigation, and no information was provided on the percent fat levels of the subjects.

Another study which found decreases on resting blood pressure in hypertensive adults was conducted by Gleichmann et al. (1989). The investigators examined the effects of a 56-week exercise program on 29 hypertensive patients, aged 43 to 73. The subjects participated in cycling on a bicycle ergometer at 25 to 125 watts for a period of 20 minutes. The frequency and specific intensity of the training program were not reported. When compared to pre-exercise values, post-exercise testing demonstrated a statistically significant decrease in resting systolic (M = 153, SD = 18 vs. M = 139, SD = 17 mmHg) and diastolic (M = 93, SD = 11 vs. M = 87, SD = 11 mmHg) blood pressure. A small reduction of 1 kg in the subject's body weight was observed. The research team concluded that physical training reduced resting blood pressure in hypertensives. No information was included on the percent fat of the subjects, nor was a hypertensive control group included in the study. In addition, the gender of the subjects was not identified.

Additionally, Jo et al. (1989) examined the effects of a 12-week exercise program in 14 males with essential hypertension. The mean age of the subjects was 43. The participants performed primarily jogging exercise twice a week for 60 minutes per session. The training intensity of the subjects was set at 50 percent of maximum oxygen consumption. The results demonstrated statistically significant reductions in both resting systolic and diastolic blood pressure levels, respectively (M = 147, SD = 17 vs. M = 136, SD = 5 mmHg; M = 98, SD = 7 vs. M = 90, SD = 5 mmHg). There were no changes in body weight. The research team concluded that physical training reduced resting blood pressure in essential hypertensives. No data were available on the percent fat levels of the participants. Additionally, no hypertensive control group was included in this investigation.

One of the three studies that used a hypertensive control group and found exercise-related decreases on resting blood pressure was conducted by Baglivo et al. (1990). The investigators examined 15 essential mild hypertensive males and females who participated in 50 minutes of lower extremity aerobic activity three times per week for three months. The authors found a statistically significant decrease in both resting systolic (M = 155, SD = 10 vs. M = 136, SD = 8 mmHg) and diastolic (M = 101, SD = 3 vs. M = 87, SD = 7 mmHg) blood pressure as a result of physical training. There were no significant changes in body weight. Additionally, none of the changes were significant for the hypertensive control group. The investigators concluded that it was prudent to prescribe aerobic exercise to mild essential hypertensive patients. Unfortunately, no information was provided on the intensity at which the subjects trained. Also, no information was provided on the percent fat levels of the subjects, nor were data partitioned according to gender.

In a well-designed study, Martin, Dubbert, and Cushman (1990) investigated the effects of a 10-week exercise program on 10 mildly hypertensive men, aged 21 to 44. The subjects trained by fast walking, jogging, and/or cycling four times per week, 30 minutes per session, at 65 to 85 percent of their maximum heart rate. Post-exercise results showed a decrease of M = 6 mmHg (M = 136, SD = 9 vs. M = 130, SD = 10 mmHg) in resting systolic pressure and M = 10 mmHg (M = 95, SD = 5 vs. M = 85, SD = 5 mmHg) in resting diastolic pressure. No changes in either body weight or percent fat levels of the subjects were observed. None of the changes in resting blood pressure were significant for the hypertensive control group. The authors concluded aerobic exercise had an independent effect on resting blood pressure in unmedicated mildly hypertensive men.

Painter et al. (1986) investigated the effects of 24 weeks of exercise training in 13 hypertensive subjects (12 males, 8 females) with a mean age of 42. The subjects participated in cycle ergometry three to four times per week for 30 to 45 minutes per session. Training was equivalent to 75 to 85 percent of maximum oxygen consumption. Post-exercise results demonstrated a statistically significant decrease of M = 24 mmHg (M = 152, SD = 34 vs. M = 138, SD = 29 mmHg) in resting systolic blood pressure. The authors concluded that exercise training reduced resting systolic blood pressure in some hypertensive patients. No information was reported on diastolic blood pressure, body weight, or percent fat levels of the participants. In addition, data separated according to gender were not reported.

Finally, Filipovsky et al. (1991) performed a study in which 77 hypertensive adults (60 males, 17 females) took part in a five-week physical training program consisting of cycle ergometry three times per week for 30 minutes per session. The training intensity of each session was 70 percent of maximum heart rate. The results demonstrated a statistically significant reduction in both resting systolic and diastolic blood pressure pre- to post-exercise (M = 157, SD = 20 vs. M = 142, SD = 20 mmHg; M = 98, SD = 10 vs. M = 89, SD = 11 mmHg). A follow-up examination on 70 of the 77 original subjects three to seven months after the training program subsided revealed statistically significant increases in both resting systolic and diastolic blood pressure when compared to immediate post-exercise (M = 162, SD = 18 vs. M = 142, SD = 20 mmHg; M = 102, SD = 11 vs. M = 89, SD = 11 mmHg) and pre-exercise blood pressures (M = 162, SD = 18 vs. M = 157, SD = 20 mmHg; M = 102, SD = 11 vs. M = 98, SD = 10 mmHg). The authors concluded that physical training had a short-term effect on decreases in resting systolic and diastolic blood pressure in hypertensives. No data on body weight or percent fat were reported in this study. In addition, no hypertensive control group was included, and data according to gender were absent.

Longitudinal Studies Finding Reductions in Resting Systolic or Diastolic Blood Pressure

In contrast to the previous studies, which found aerobic exercise-induced decreases in both resting systolic and diastolic blood pressure, Bonanno and Lies (1974) found significant decreases in resting systolic pressure only. The investigators examined a small number of middle-aged essential hypertensive men (N = 12) and a hypertensive control group (N = 15) over a period of 12 weeks. The subjects exercised aerobically by walking and jogging three times per week for 40 to 55 minutes per session at 70 to 85 percent of maximal heart rate. For the exercise group there was a statistically significant reduction in resting systolic blood pressure only (M = 148 vs. M = 135 mmHg). For the hypertensive control group which was included in the study, there was a statistically significant reduction in resting diastolic blood pressure (M = 101 vs. M = 90 mmHg). Despite these results, the researchers concluded that a physical training program was a valuable adjunctive therapy in patients who were at a high risk for coronary artery disease and had hypertension. No data were provided on percent fat or post-exercise body weight. In addition, no standard deviations were reported with these results.

Another study which reported significant aerobic exercise-induced decreases in resting systolic pressure, but not diastolic pressure, was conducted by Urata et al. (1987). In this study the investigators examined the effects of a 10-week exercise program on 10 males and females, aged 32 to 60, diagnosed with essential hypertension. The subjects trained on a cycle ergometer three times per week for 65 minutes per session at 40 to 65 percent of maximum oxygen consumption. The results of the study revealed statistically significant reductions in resting systolic pressure (M = 153, SD = 12 vs. M = 144, SD = 15 mmHg) as a result of training. Changes in resting diastolic pressure were not significant. In addition, there were no changes in body weight for the exercise group. None of the changes were significant for the hypertensive control groups. It was concluded that mild exercise resulted in an anti-hypertensive effect on individuals with essential hypertension. No data were provided on the percent fat levels of the participants. In addition, blood pressure results according to gender were not reported.

A third study which found exercise-induced decreases in resting systolic pressure only was conducted by Barry et al. (1966). This group examined the effects of a 12-week physical training program on eight essential hypertensive males and females (aged 38 to 78) who cycled for 40 minutes, three times per week, at a heart rate of 130 beats per minute. The results of the study demonstrated a statistically significant decrease in resting systolic blood pressure (M = 147, SD = 21 vs. M = 127, SD = 7 mmHg) pre- to post-exercise. There were no statistically significant decreases in resting diastolic blood pressure. In addition, none of the changes in resting systolic and diastolic blood pressure were significant for the hypertensive control group included in the study. It was concluded that aerobic exercise decreased resting systolic blood pressure in hypertensives. No data were reported on the percent fat levels of the participants, and data according to gender were not reported.

One study which reported data partitioned by gender was conducted by Weber, Barnard, and Roy (1983). The investigators examined the effects of physical training on hypertensive male (N = 43) and female (N = 27) subjects, aged 60 to 80, over a four-week period. The subjects walked and/or jogged 15 times per week for 140 minutes per session at 70 percent of their predicted heart rate. The overall results of the study demonstrated statistically significant decreases in resting systolic pressure for males and females (M = 144 vs. M = 132 mmHg). None of the overall changes for resting diastolic pressure were significant. When data were partitioned according to gender, statistically significant decreases were reported for both resting systolic (M = 14 mmHg) and diastolic (M = 5 mmHg) blood pressure in men. For the women, significant reductions were noted only for resting systolic pressure (M = 9 mmHg). The authors concluded that aerobic exercise reduced resting blood pressure in hypertensive adults. No control group was included in this study, and no information on the percent fat levels of the subjects was given.

The only study which found significant aerobic exercise-induced decreases in resting diastolic blood pressure, but not systolic, was conducted by Duncan et al. (1985). The effects of 16 weeks of walking and jogging on changes in resting systolic and diastolic blood pressure were investigated in 44 hypertensive males. The subjects trained at 70 to 80 percent of maximum heart rate, three times per week for 60 minutes per session. Results showed statistically significant reductions in diastolic blood pressure ($\underline{M}$ = 94, $\underline{SD}$ = 6 vs. $\underline{M}$ = 87, $\underline{SD}$ = 4 mmHg). The results for systolic blood pressure were not statistically significant. In addition, none of the changes were significant for the hypertensive control group included in the study. Furthermore, there were no changes in body weight for either of the groups. The investigators concluded that aerobic exercise reduced resting blood pressure in hypertensive patients. No data were provided on the percent fat of the subjects.

Longitudinal Studies Finding No Reductions in Both Resting Systolic and Diastolic Blood Pressure

Some studies, such as the one conducted by Kukkonen, Rauramaa, Voutilainen, and Lansimies (1982) found no significant aerobic exercise-induced decreases in either resting systolic or diastolic blood pressure. In this study, the researchers investigated the effects of a 16-week physical training program on 13 middle-aged men (aged 35 to

50) with borderline hypertension. The subjects took part in cycling on an ergometer three times per week for 50 minutes per session. Intensity of training was equivalent to approximately 66 percent of maximum heart rate. None of the post-exercise measurements for resting systolic and diastolic blood pressure, when compared with pre-exercise values in the same subjects, were statistically significant. Post-exercise resting systolic pressure actually increased from $M = 142$, $SD = 10$ to $M = 146$, $SD = 14$ mmHg. There were no significant changes in body weight for the exercise group. In addition, none of the changes in blood pressure were significantly different for the hypertensive control group included in the study. Despite these results, the research team concluded that exercise training was worth considering as a treatment modality for middle-aged borderline hypertensives. No information on percent fat levels of the subjects was provided.

One of the four studies reviewed which measured blood pressure directly was conducted by Johnson and Grover (1967). This pair investigated the effects of a 10-week training program on four patients with essential hypertension. The subjects walked and/or ran on a treadmill three times per week for 35 minutes per session. The intensity of their training was at a heart rate of 160 beats per minute. Blood pressure results (measured invasively) showed an increase in both resting systolic and diastolic levels. Systolic blood pressure increased from *M* = 188 to *M* = 195 mmHg, while diastolic blood pressure increased from *M* = 103 to *M* = 105 mmHg. The investigators concluded that physical training did not reduce resting blood pressure levels in hypertensives. No data were provided on gender, body weight, or percent fat levels of the participants. In addition, no hypertensive control group was included, and standard deviations for these data were absent.

A third study, conducted by Ressl, Chrastek, and Jandova (1977) also found no significant difference in resting blood pressure levels as a result of aerobic exercise. These investigators examined the effects of four weeks of physical training in 10 males, aged 38 to 53, with essential hypertension. The subjects participated in cycle ergometry exercise five times per week for 36 minutes per session at an intensity equal to 70 percent of their maximum oxygen consumption. Intra-arterial blood pressure measurements demonstrated no statistically significant effects on either resting systolic or diastolic blood pressure. The subjects decreased their body weight by *M* = 3 kg. The researchers concluded that exercise training did not reduce resting systolic and diastolic blood pressure. There was no information on percent fat levels of the participants, and no hypertensive control group was included in this study.

Finally, De Plaen and Detry (1980) also found no significant aerobic exercise-induced changes in resting blood pressure. The investigators examined the effects of three months of exercise on a total of five male and female subjects with established arterial hypertension. The subjects participated in a combination of aerobic activities three times per week for 60 minutes at 50 to 70 percent of their maximum oxygen consumption. Both resting systolic and diastolic blood pressure, when measured directly and indirectly, were not significantly reduced (M = 162, SD = 26 vs. M = 158, SD = 29 mmHg; M = 104, SD = 14 vs. M = 104, SD = 14 mmHg). There was a decrease in body weight of M = 2 kg for subjects. In addition, none of the changes in resting blood pressure were significant for the hypertensive control group included in the study. The researchers concluded that physical training had no specific hypotensive effect in patients with established arterial hypertension. No information was provided on percent fat, and data according to gender were absent.

Longitudinal Studies Finding Differences in Resting Blood Pressure Partitioned by Miscellaneous Variables

While the previous studies have found either changes or no changes in one or both blood pressure measures, other investigators have reported differences between hypertensive groups who were partitioned according to diet, training intensity, mode of training, responses to maximal exercise testing, and method of blood pressure measurement.

For example, Nomura et al. (1984) investigated the effects of diet and physical training on 21 males and females, aged 25 to 52. The subjects participated in cycle ergometry 20 times per week, nine minutes per session, at an intensity equivalent to 75 percent of their maximum oxygen consumption. The subjects were divided into two groups, one group (N = 7) consumed 170 milliequivalents of salt per day, while a second group (N = 14) consumed 34 milliequivalents of salt per day. While both groups exhibited a decrease in resting systolic and diastolic blood pressure levels, only group two displayed changes which were statistically significant. There was a decrease of M = 11 mmHg (M = 141, SD = 18 vs. M = 130, SD = 13 mmHg) in resting systolic pressure and M = 8 mmHg (M = 93, SD = 14 vs. M = 85, SD = 8 mmHg) in resting diastolic pressure. There were small, nonsignificant changes in body weight for the two groups. Despite the fact that only the low-salt group displayed statistically significant reductions in resting blood pressure, the investigators concluded that physical training reduced resting blood pressure in hypertensives. No information was provided on the percent fat of the subjects. In addition, no hypertensive control group was included in this study.

A second study, conducted by Hagberg, Montain, Martin, and Ehsani (1989) examined the effects of 37 weeks of low- or moderate-intensity exercise on 19 essential hypertensive men and women with a mean age of 65 years. One group (N = 11) participated in a low-intensity (50 percent of maximum oxygen consumption) exercise program consisting of a combination of aerobic activities performed three times per week for 60 minutes per session. A second group (N = 8) performed moderate-intensity (70 to 85 percent of maximum oxygen consumption) exercise consisting of fast walking, jogging, cycle ergometry, and treadmill walking three times per week for a period of 60 minutes per session. For the moderate-intensity training group, there was a statistically significant reduction in both resting systolic (M = 8 mmHg) and diastolic (M = 9 mmHg) blood pressure. The low-intensity group demonstrated a significant reduction in resting systolic pressure only (M = 5 mmHg). There were small, nonsignificant changes in body weight for the two groups. The authors concluded that low-intensity training lowered resting blood pressure levels as much or more than moderate-intensity training in older persons with essential hypertension. No hypertensive control group was included in this investigation.

Cleroux, Peronnet, and de Champlain (1987) investigated the effects of 20 weeks of either jogging or cycle ergometry exercise in 12 hypertensive males and females. Seven subjects participated in cycle ergometry, while the other five jogged. All participants exercised three times per week for 20 to 45 minutes per session at 60 percent of their maximum oxygen consumption. Compared to pre-exercise values, standing post-exercise measurements revealed a statistically significant decrease in both resting systolic and diastolic blood pressure (M = 145 vs. M = 135 mmHg; M = 98 vs. M = 90 mmHg) for those who participated in cycle ergometry. While the jogging group also decreased resting systolic and diastolic blood pressure (M = 140 vs. M = 130 mmHg; M = 95 vs. M = 90 mmHg), these changes were not statistically significant. In addition, none of the changes in resting blood pressure were significant for either of the groups when resting blood pressure was measured in the supine position. The authors concluded that physical training did not clearly demonstrate a lowering effect on resting blood pressure. No information on body weight and no control group were used in this study. Furthermore, standard deviations for this data were absent, and separate data for males and females were not provided.

Finally, Attina, Giuliano, Arcangeli, Musante, and Cupelli (1986) examined the effects of 52 weeks of physical training on 26 men with borderline hypertension. The subjects were divided into two groups on the basis of blood pressure responses to maximal exercise testing: normal responses (N = 14) and abnormal responses (N = 12). The subjects participated in a combination of activities (jogging, rowing, and gymnastics) for at least three hours per week. The frequency and intensity of these sessions were not reported. Results of the study revealed statistically significant decreases in resting systolic and diastolic blood pressure for the normal response group ($\underline{M}$ = 141, $\underline{SD}$ = 10 vs. $\underline{M}$ = 136, $\underline{SD}$ = 12 mmHg; $\underline{M}$ = 87, $\underline{SD}$ = 6 vs. $\underline{M}$ = 80, $\underline{SD}$ = 8 mmHg). None of the changes for the abnormal response group were statistically significant. The investigators concluded that borderline hypertensives with normal responses to maximal exercise testing reduced resting blood pressure as a result of regular physical training, while those with abnormal responses did not. No information on body weight or percent fat were reported for this study. Also, no control group was used.

The only hypertensive study which examined the effects of aerobic exercise over a 24-hour period was conducted by Seals and Reiling (1991). Twenty-six hypertensive subjects (nine men and five women) participated in aerobic exercise for six months. The remaining 12 subjects (10 men and 2 women) acted as hypertensive controls. Eighteen of the subjects, consisting of 10 exercisers and 8 controls, participated in an additional six months of training. During the first six months of training, subjects exercised for an average of $\underline{M}$ = 27.6 weeks, $\underline{M}$ = 3.5 days per week, for $\underline{M}$ = 41 minutes per day, at $\underline{M}$ = 47 percent of maximal heart-rate reserve. Ten of the exercisers continued to train for an additional six months. Subjects walked an average of M = 3.6 days per week, for M = 50 minutes per day, at an intensity of M = 57 percent of maximal heart-rate reserve. Casual resting blood pressure, measured by auscultatory cuff method, resulted in statistically significant decreases for resting systolic and diastolic blood pressure among all exercise groups. Results were irrespective of training duration or position of measurement (supine, sitting, and standing). Control groups also demonstrated significant decreases in resting systolic blood pressure in the supine and sitting positions at both 6 and 12 months and in the standing position after six months. One control group did not exhibit any significant reductions at either 6 or 12 months. Reductions in resting systolic and diastolic blood pressure were significant for both exercise and control groups over 6 and 12 months, irrespective of position of measurement. In contrast, 24-hour ambulatory blood pressure, also measured by auscultatory cuff method, resulted in significant reductions only on resting systolic blood pressure for the 12-month exercise group. Changes in body fat were not significant. The investigators concluded that low-intensity aerobic exercise produced only small decreases in 24-hour levels of arterial pressure. In addition, it was concluded that aerobic exercise-induced reductions in casually determined blood pressure at rest did not always reflect the magnitude or direction of changes in arterial pressure throughout an entire day.

Summary of Longitudinal Studies Reviewed

Of the 32 studies reviewed, 18 (Baglivo et al., 1990; Boyer & Kasch, 1970; Cade et al., 1984; Choquette & Ferguson, 1973; deVries, 1970; Filipovsky et al., 1991; Gleichmann et al., 1989; Hanson & Nedde, 1970; Jo et al., 1989; Kinoshita et al., 1988; Kiyonaga et al., 1985; Martin et al., 1990; Nelson et al., 1986; Painter et al., 1986; Roman et al., 1981; Rudd & Day, 1967; Tanabe et al., 1988; Wilmore et al., 1970) found aerobic exercise-induced decreases in both resting systolic and diastolic blood pressure. Four of the studies (Barry et al., 1966; Bonanno & Lies, 1974; Urata et al., 1987; Weber et al., 1983) reported significant decreases in resting systolic blood pressure, but not diastolic pressure. Only one study (Duncan et al., 1985) found significant reductions in resting diastolic blood pressure, but not systolic. In addition, four of the studies (De Plaen & Detry, 1980; Johnson & Grover, 1967; Kukkonen et al., 1982; Ressl et al., 1977) reported no significant reductions in both resting systolic and diastolic blood pressure. Finally, five other studies found differences in resting blood pressure partitioned according to: (1) diet (Nomura et al., 1984); (2) intensity of training (Hagberg et al., 1989); (3) mode of training (Cleroux et al., 1987); (4) responses to maximal exercise testing (Attina et al., 1986); and (5) method of blood pressure measurement (Seals & Reiling, 1991). Subjective observation of these studies revealed no common trends associated with exercise-induced changes in resting blood pressure.

Previous Reviews

In addition to the studies just discussed, several traditional review articles dealing with the effects of exercise on hypertension have led to differing conclusions. For example, Tipton (1984) in his review on exercise and hypertension, concluded that exercise alone could benefit those who were hypertension-prone, regardless of age, as well as those whose resting blood pressure was approximately 140 mmHg systolic and/or 90 mmHg diastolic. In addition, he stated that the magnitude and direction of changes in blood pressure as a result of exercise appeared to be dependent upon: (1) the age of the subject; (2) the nature, duration, and intensity of the training program; and (3) other countermeasures. The magnitude of reduction in resting blood pressure, according to the author, ranges from 5 to 25 mmHg (systolic) to 3 to 15 mmHg (diastolic).

Conversely, Seals and Hagberg (1984) in their review concluded that the average reduction in resting blood pressure as a result of aerobic exercise was 9 mmHg for systolic blood pressure and 7 mmHg for diastolic pressure.

The authors suggested that the magnitude of these reductions may be of greater relative benefit to those individuals with borderline or mild hypertension versus those individuals with moderate or severe hypertension. However, they expressed caution in the interpretation of these findings due to what they felt was poor study design. Because of poor study design and methodological problems, the reviewers concluded that it was inadequate to recommend exercise training as a substitute for pharmacological intervention in the treatment of hypertension.

A third review by McMahon and Palmer (1985) concluded that: (1) aerobic activity benefits certain hypertensive patient subgroups (overweight, hyperdynamic circulation, elevated cardiac output at rest, elevated sympathetic nervous system activity); (2) the antihypertensive effect of exercise, independent of other nonpharmacological measures, is still unclear; and (3) the patient with moderate and severe hypertension should receive antihypertensive medication before starting an exercise program.

More recently, Gordon et al. (1990) in their review cited a reduction in resting systolic and diastolic blood pressure of 10.8 mmHg and 8.2 mmHg, respectively, as a consequence of physical training in hypertensives. The authors concluded that aerobic exercise could be used both as an intervention and as an adjunct to pharmacological therapy for patients with mild hypertension. They recommended an exercise training program corresponding to 60 to 85 percent of maximal heart rate, with the frequency and duration sufficient enough to achieve a weekly energy expenditure of between 14 and 20 kilocalories per kilogram of body weight.

Finally, Tipton (1991), in an updated review on the effects of exercise on human hypertension, confirmed his previous conclusions that sufficient justification existed to recommend exercise training as a separate countermeasure in any program designed to lower resting blood pressure in hypertensive populations. Furthermore, Tipton stated that most researchers were prescribing aerobic endurance exercises between 40 to 70 percent of maximum oxygen consumption. Intensities greater than this, according to Tipton, attenuated decreases in resting blood pressure.

From the aforementioned studies and reviews, it is obvious that research is still somewhat conflicting and incomplete concerning the effects of aerobic exercise on human hypertension. Additional quantitative review on this topic is needed to clear up some of the discrepancies in the current literature.

CHAPTER 3

Methods

Literature Search

Thirty-two longitudinal journal studies (see Appendix A), published in English and conducted over the last 25 years from 1966 to 1991, were obtained through ERIC, Medline, and Sport computer searches during the 1990 to 1991 academic year. Since previous research by Lokey, Tran, Wells, Myers, and Tran (1991) found only 44 percent of the studies used in their meta-analysis from computer searches, extensive cross-referencing and hand searches were performed. Selection of studies for subsequent meta-analysis was limited to those in which lower extremity aerobic exercise was the primary training mode in hypertensive adults with resting blood pressures greater than 139 mmHg systolic and/or 89 mmHg diastolic (American Heart Association, 1989).

Coding and Classifying Variables

All studies that met the criteria for analysis were coded. Separate coding sheets were developed for systolic and diastolic exercise and control groups. A total of 17 variables were recorded for the exercise groups, while 12 were documented for each of the control groups (Appendix B). For the systolic and diastolic exercise groups, seven of the variables represented the physical characteristics of the subjects, five represented the blood pressure results, and five described the exercise programs. Systolic and diastolic control groups were coded for seven variables which represented the physical characteristics of the subjects and five variables representing blood pressure results.

Statistical Analysis

In meta-analytic research it is necessary to choose a common metric in order to statistically describe how characteristics of studies interact with each other. The unit used in this study to measure change was the effect size. This was calculated by subtracting the post-exercise value from the pre-exercise value, divided by the pre-exercise standard deviation for each group. Therefore, decreases in resting systolic and diastolic blood pressure levels yielded a positive effect size. For studies in which means and standard deviations were not available, effect sizes were estimated according to the formulas provided by Glass, McGaw, and Smith (1981).

The overall effectiveness of the exercise programs in reducing blood pressure was established by applying a *t*-distribution to exercise and control groups. This was done in order to establish whether or not the resultant effect-size changes were significantly different from zero. These overall results were examined at several levels of study characteristics, subjects, types, physiological characteristics, and design. Differences between two groups, both representing effect-size changes significantly different from zero, were accomplished by use of independent *t*-tests. Differences between more than two groups were determined by the use of one-way analysis of variance.

Relationships between resting systolic and diastolic blood pressure mean effect-size changes and selected variables were accomplished by use of Pearson correlation coefficients. While the maximum correlation between any two variables is ± 1.00, this can only be accomplished when the variables are identically distributed. Since this is not the case with this investigation, the maximum correlation between any two variables is expected to be less than unity. Thus, obtained values, although not statistically significant, may indicate a strong relationship. Because decreases in resting blood pressure levels yielded a positive effect size, a positive correlation coefficient indicated that decreases were associated with larger values. Since there were no significant relationships or differences among number of subjects; number of groups; duration, position, or type of blood pressure measurement; mode of training; presence or absence of a hypertensive control group; and mean affect-size changes in resting systolic and diastolic blood pressure, no weighting procedure was employed. The .05 level of probability was considered significant.

CHAPTER 4

Results and Discussion

The results and discussion were presented together in order to improve readability and cohesiveness. The first section briefly describes study, subject, and training program outcomes. The second section describes differences between variables. The third section deals with relationships between physical characteristics and aerobic exercise-induced changes in resting blood pressure. The final section describes relationships between training programs and exercise-related changes in resting blood pressure.

Results of Literature Search

The 32 training studies selected for analysis included a total of 43 exercise groups and 11 control groups. A total of 927 subjects (781 experimental, 146 hypertensive control) were used in these studies (see Table 1). The number of subjects per study ranged from 4 to 77, with an average of 18 subjects per study.

The physical characteristics of subjects in the systolic and diastolic exercise and control groups are shown in Table 2. The age for systolic and diastolic exercise and control groups yielded a combined age range of 21 to 88 years, M = 48.43. The average height was M = 170.22 cm,

Table 1

Summary of Study Characteristics

Study and group totals

Characteristic	N (total)	N (systolic)	N (diastolic)
Studies included	32	30	25
Exercise groups	43	41	33
Control groups	11	10	9

Subject totals

	Means and S.D.'s		
Characteristic	N	Mean	S.D.
Systolic			
Exercise	739	18	17
Control	132	13	8
Total	871	18	16
Diastolic			
Exercise	587	18	16
Control	111	12	4
Total	698	17	15
Systolic and diastolic			
Exercise	781	19	18
Control	146	13	7
Total	927	18	17

Table 2

Initial Subject Characteristics

Systolic exercise and control groups			
	Means and S.D.'s		
Characteristic	N	Mean	S.D.
Exercise			
Age (yr)	21	46.57	9.39
Height (cm)	5	170.88	7.84
Weight (kg)	27	72.42	8.28
Body fat (%)	8	25.58	3.95
Control			
Age (yr)	4	50.75	7.41
Height (cm)	3	169.56	10.88
Weight (kg)	8	77.12	10.04
Body fat (%)	2	21.20	1.69
Diastolic exercise and control groups			
Exercise			
Age (yr)	19	47.21	9.12
Height (cm)	6	170.88	7.84
Weight (kg)	24	73.65	9.43
Body fat (%)	7	26.71	3.90
Control			
Age (yr)	5	49.20	7.29
Height (cm)	3	169.56	10.88
Weight (kg)	8	76.87	10.55
Body fat (%)	2	28.20	8.20

Note: N = number of groups reporting data.

while the average weight was M = 75.01 kg. The average percent body fat of the subjects was M = 25.42.

Characteristics of the training programs are shown in Table 3. Length of training for systolic and diastolic exercise groups yielded a combined range of 3 to 56 weeks, with an overall mean average of 15.72 weeks. The frequency of each workout ranged from 3 to 20 sessions per week (M = 4.38), while the intensity spanned 58 to 100 percent (M = 72.79) of maximum heart rate. The duration of each session ranged from 9 to 210 minutes, with an average workout lasting 53.65 minutes.

Results of Differences Between Variables

The first part of this section reported the overall differences between pre- and post-exercise effect-size measures on resting systolic and diastolic blood pressure. The second segment of this section reported the categorical (mild, moderate, and severe) differences between pre- and post-exercise effect-size measures on resting systolic and diastolic blood pressure. The final portion of this section discussed the results of overall and categorical changes which occurred on resting blood pressure as a result of aerobic training.

Overall Changes

As can be seen in Table 4, exercise groups reduced resting systolic (M = 12.26 mmHg) and diastolic

Table 3

Training Program Characteristics

Characteristic	N[a]	Mean	S.D.
Systolic and diastolic groups			
	Means and S.D.'s		
Systolic			
Length (weeks)	41	15.66	12.23
Frequency (days/week)	39	4.52	4.53
Intensity (% MHR)[b]	24	73.20	9.25
Duration (minutes/session)	38	55.31	35.27
Diastolic			
Length (weeks)	33	15.78	11.21
Frequency (days/week)	31	4.25	4.28
Intensity (% MHR)[b]	22	72.38	9.15
Duration (minutes/session)	32	52.00	30.87

[a]N = number of groups reporting data.

[b]% MHR = percent maximum heart rate.

Table 4

Overall Blood Pressure Results

Characteristic	N[a]	Mean	S.D.
Systolic exercise and control groups			
Exercise			
Pre-exercise (mmHg)	41	153.60	11.72
Post-exercise (mmHg)	41	141.34	14.18
Absolute change (mmHg)	41	12.26	9.77
Relative change (%)[b]	41	7.98	5.88
Control			
Pre-exercise (mmHg)	10	149.10	5.70
Post-exercise (mmHg)	10	144.40	6.16
Absolute change (mmHg)	10	4.70	4.80
Relative change (%)[b]	10	3.15	3.15
Diastolic exercise and control groups			
Exercise			
Pre-exercise (mmHg)	33	99.15	5.99
Post-exercise (mmHg)	33	89.90	6.26
Absolute change (mmHg)	33	9.25	5.51
Relative change (%)[b]	33	9.33	5.11
Control			
Pre-exercise (mmHg)	9	99.44	6.16
Post-exercise (mmHg)	9	96.44	5.50
Absolute change (mmHg)	9	3.00	5.02
Relative change (%)[b]	9	3.02	4.98

Note: "Means and S.D.'s" spans the N, Mean, and S.D. columns.

[a]N = number of groups reporting data.

[b]Relative change calculated by dividing absolute change by pre-exercise values, multiplied by 100.

(M = 9.25 mmHg) blood pressure levels. Resting systolic pressure decreased from M = 153.60, SD = 11.72 to M = 141.34, SD = 14.18 mmHg. Resting diastolic pressure declined from M = 99.15, SD = 5.99 to M = 89.90, SD = 6.26 mmHg. Control groups reduced resting systolic and diastolic blood pressure by M = 4.70 and M = 3.00 mmHg, respectively.

Table 5 represents effect size and t-distribution analysis for overall blood pressure results. For the exercise groups, resting systolic blood pressure yielded an effect size of M = .96, SD = .82. Resting diastolic blood pressure produced an effect size of M = 1.55, SD = 1.48. Both effect sizes represented t-intervals significantly different from zero. Effect sizes of M = .74, SD = .98 and M = .32, SD = .80 were noted for systolic and diastolic control groups, respectively. Neither control group effect size produced a t-interval significantly different from zero.

Categorical Changes

The results for resting systolic and diastolic blood pressure partitioned by categories may be found in Tables 6 and 7. As can be seen in Table 6, aerobic exercise-induced reductions of M = 8.83, M = 15.00, and M = 16.37 mmHg occurred for mild, moderate, and severe systolic categories, respectively. Resting diastolic pressure was also reduced (see Table 7). Mild resting diastolic pressure was reduced

Table 5

Analysis of Data for Overall Blood Pressure Results

Effect-size data

Characteristic	N[a]	Mean	S.D.
	Means and S.D.'s		
Exercise			
Systolic (mmHg)	41	.96	.82
Diastolic (mmHg)	33	1.55	1.48
Control			
Systolic (mmHg)	10	.74	.98
Diastolic (mmHg)	9	.32	.80

T-distribution analysis

Characteristic	Confidence (%)	T-interval
Exercise		
Systolic (mmHg)	95	.70 - 1.22*
Diastolic (mmHg)	95	1.02 - 2.08*
Control		
Systolic (mmHg)	95	.03 - 1.44
Diastolic (mmHg)	95	-.30 - .93

[a]N = number of groups reporting data.

*Significantly different from zero at $p < .05$.

Table 6

Systolic Blood Pressure Changes by Category

Systolic exercise groups			
	Means and S.D.'s		
Characteristic	N[a]	Mean	S.D.
Mild (140-149 mmHg)			
Pre-exercise (mmHg)	18	144.00	3.27
Post-exercise (mmHg)	18	135.17	5.12
Absolute change (mmHg)	18	8.83	5.80
Relative change (%)[b]	18	6.13	3.97
Moderate (150-159 mmHg)			
Pre-exercise (mmHg)	15	155.00	3.09
Post-exercise (mmHg)	15	140.00	6.13
Absolute change (mmHg)	15	15.00	4.81
Relative change (%)[b]	15	9.68	3.10
Severe (>159 mmHg)			
Pre-exercise (mmHg)	8	172.62	9.25
Post-exercise (mmHg)	8	156.25	25.35
Absolute change (mmHg)	8	16.37	18.85
Relative change (%)[b]	8	9.48	11.01

[a]N = number of groups reporting data.

[b]Relative change calculated by dividing absolute change by initial values, multiplied by 100.

Table 7

Diastolic Blood Pressure Changes by Category

Diastolic exercise groups			
	Means and S.D.'s		
Characteristic	N[a]	Mean	S.D.
Mild (90-95 mmHg)			
Pre-exercise (mmHg)	11	93.09	2.11
Post-exercise (mmHg)	11	85.00	3.43
Absolute change (mmHg)	11	8.09	2.98
Relative change (%)[b]	11	8.69	3.22
Moderate (96-100 mmHg)			
Pre-exercise (mmHg)	11	97.82	1.54
Post-exercise (mmHg)	11	89.82	4.19
Absolute change (mmHg)	11	8.00	3.49
Relative change (%)[b]	11	8.18	3.78
Severe (>100 mmHg)			
Pre-exercise (mmHg)	11	106.09	3.91
Post-exercise (mmHg)	11	94.63	6.77
Absolute change (mmHg)	11	11.46	8.25
Relative change (%)[b]	11	10.80	7.53

[a]N = number of groups reporting data.

[b]Relative change calculated by dividing absolute change by initial values, multiplied by 100.

by M = 8.09 mmHg, while moderate resting pressure declined by M = 11.46 mmHg. Severe resting pressure decreased by M = 11.46 mmHg.

Tables 8 and 9 illustrate within and between groups analysis on categorical data. As can be seen in Table 8, systolic effect-size changes of M = .73, SD = .60; M = 1.14, SD = .60; and M = 1.21, SD = 1.37 were observed for mild, moderate, and severe categories, respectively. Within groups, t-distribution analysis revealed t-intervals significantly different from zero among all categories. One-way analysis of variance between groups produced a nonsignificant value of F = 1.543. Table 9 represents within and between groups analysis for diastolic categorical data. Effect sizes of M = 1.27, SD = 1.12; M = 1.07; SD = .61; and M = 2.23, SD = 2.17 were noted for mild, moderate, and severe categories, respectively. Within groups t-distribution analysis revealed t-intervals significant from zero among all categories. One-way analysis of variance between groups yielded a nonsignificant value of F = 2.013.

Discussion

Examination of the overall results showed that of the 41 systolic exercise groups chosen for this meta-analysis, 33 (approximately 80 percent) representing 25 of 30 studies (Attina et al., 1986; Baglivo et al., 1990; Barry et al., 1966; Bonanno & Lies, 1974; Boyer & Kasch, 1970;

Table 8

Systolic Analysis of Data for Blood Pressure Categories

Systolic effect-size data

Category	N[a]	Means and S.D.'s Mean	S.D.
Mild (140-149 mmHg)	18	.73	.60
Moderate (150-159 mmHg)	15	1.14	.60
Severe (>159 mmHg)	8	1.21	1.37

T-distribution analysis

Category	Confidence (%)	T-interval
Mild (140-149 mmHg)	95	.43 - 1.02*
Moderate (150-159 mmHg)	95	.81 - 1.48*
Severe (>159 mmHg)	95	.06 - 2.37*

One-way analysis of variance

Source	DF	SS	MS	F	Significance
Treatment	2	1.9886	0.9943	1.543	.22683
Error	38	24.4851	0.6443		
Total	40	26.4737			

[a]N = number of groups reporting data.

*Significantly different from zero at $p < .05$.

Table 9

Diastolic Analysis of Data for Blood Pressure Categories

Diastolic effect-size data

Category		Means and S.D.'s	
	N[a]	Mean	S.D.
Mild (90-95 mmHg)	11	1.27	1.12
Moderate (96-100 mmHg)	11	1.07	.61
Severe (>100 mmHg)	11	2.23	2.17

T-distribution analysis

Category	Confidence (%)	T-interval
Mild (90-95 mmHg)	95	.52 - 2.02*
Moderate (96-100 mmHg)	95	.66 - 1.48*
Severe (>100 mmHg)	95	.78 - 3.69*

One-way analysis of variance

Source	DF	SS	MS	F	Significance
Treatment	2	8.5427	4.2713	2.013	.15124
Error	30	63.6609	2.1220		
Total	32	72.2036			

[a]N = number of groups reporting data.

*Significantly different from zero at $p < .05$.

Cade et al., 1984; Cleroux et al., 1987; deVries, 1970; Filipovsky et al., 1991; Gleichmann et al., 1989; Hagberg et al., 1989; Hanson & Nedde, 1970; Jo et al., 1989; Kinoshita et al., 1988; Kiyonaga et al., 1985; Nelson et al., 1986; Nomura et al., 1984; Painter et al., 1986; Roman et al., 1981; Rudd & Day, 1967; Seals & Reiling, 1991; Tanabe et al., 1988; Urata et al., 1987; Weber et al., 1983; Wilmore et al., 1970) found significant exercise-related reductions in overall resting systolic blood pressure.

For diastolic blood pressure, 24 of the 33 exercise groups (approximately 73 percent), representing 20 of 25 studies (Baglivo et al., 1990; Boyer & Kasch, 1970; Cade et al., 1984; Choquette & Ferguson, 1973; Cleroux et al., 1987; Duncan et al., 1985; Filipovsky et al., 1991; Gleichmann et al., 1989; Hagberg et al., 1989; Hanson & Nedde, 1970; Jo et al., 1989; Kinoshita et al., 1988; Kiyonaga et al., 1985; Martin et al., 1990; Nelson et al., 1986; Nomura et al., 1984; Roman et al., 1981; Rudd & Day, 1967; Seals & Reiling, 1991; Tanabe et al., 1988), reported significant aerobic exercise-induced reductions in hypertensive adults.

When exercise-induced changes in resting blood pressure were examined categorically, all three categories in both systolic and diastolic groups decreased resting blood pressure levels significantly. However, none of the changes between categories were significantly different from each other. Despite the fact that these results were not significant, a general tendency was for absolute decreases in both groups to be greater as the severity of resting blood pressure increased. However, for moderately and severely hypertensive adults, it appears that exercise-induced reductions are not large enough to bring resting systolic and diastolic blood pressure significantly below 140 and 190 mmHg, respectively (see Tables 6 and 7). This is in sharp contrast to the findings of Hanson and Nedde (1970) who reported decreases large enough to bring resting systolic and diastolic blood pressure levels in moderate and severely hypertensive adults down to normal levels. One of the reasons for the discrepancy of results may be the method of blood pressure measurement the investigators used. Hanson and Nedde's assessment of blood pressure was determined by the direct intra-arterial method. Although it appears to be more valid, it is almost always based on a single measurement during one day. Because it is well-documented that blood pressure is extremely variable, the accuracy of these results may be questioned. The majority of studies (27 of the 32) analyzed in this meta-analysis used repeated measurements by indirect auscultatory cuff method. It is possible that our meta-analysis results are more reflective of the true magnitude of change in resting blood pressure.

As opposed to the inability of aerobic exercise to normalize resting blood pressure levels in moderate and severely hypertensive adults, reductions in resting systolic and diastolic blood pressure in mild hypertensives appear to be large enough to normalize these pressure levels (see Tables 6 and 7). The results of this investigation are in agreement with the majority of previous studies on resting systolic (Barry et al., 1966; Bonanno & Lies, 1974; Cleroux et al., 1987; deVries, 1970; Duncan et al., 1985; Jo et al., 1989; Nelson et al., 1986; Nomura et al., 1984; Seals & Reiling, 1991; Tanabe et al., 1988; Weber et al., 1983; Wilmore et al., 1970) and diastolic (Cade et al., 1984; Choquette & Ferguson, 1973; Cleroux et al., 1987; Duncan et al., 1985; Gleichmann et al., 1989; Hagberg et al., 1989; Hanson & Nedde, 1970; Martin et al., 1990; Nomura et al., 1984; Rudd & Day, 1967; Seals & Reiling, 1991) blood pressure in mild hypertensive adults. In addition to these studies, conclusions in reviews by Gordon et al. (1990), McMahon and Palmer (1985), Seals and Hagberg (1984), and Tipton, (1984, 1991) were also consistent with the results of this investigation. Only two studies (Attina et al., 1986; Kukkonen et al., 1982) did not demonstrate a normalization of resting systolic blood pressure in mild hypertensives. In the case of Attina et al.'s study, the inability to normalize resting blood pressure only occurred in those individuals who experienced abnormal responses to maximal stress testing.

The results of this meta-analysis are consistent with the majority of individual exercise group's findings that aerobic exercise reduces resting systolic and diastolic blood pressure in hypertensive adults. Traditional, narrative reviews (Seals & Hagberg, 1984; Tipton, 1984, 1991) have criticized the results of experimental studies on hypertensives because of poor study design and methodological shortcomings. Seals and Hagberg (1984) even went so far as to cite these factors as the primary reasons for concluding that inadequate information existed to recommend exercise training as a nonpharmacological therapy in the treatment of hypertension. Even if this is true, this meta-analytic review may have accounted for these factors, as Glass (1977) has suggested, "because of randomization of design flaws and problems across a set of studies, it is possible that many weak studies can add up to a strong conclusion" (p. 356).

It appears that aerobic exercise may be used alone as a nonpharmacological treatment for the reduction of resting systolic and diastolic blood pressure in mild hypertensive adults. For those individuals with moderate and severe hypertension, a combination of aerobic exercise and other nonpharmacological and/or pharmacological interventions may be necessary for the normalization of resting systolic and diastolic blood pressure.

Despite these results, the findings of this investigation should be interpreted with caution. Recent research (Devereux & Pickering, 1988) has demonstrated that 24-hour ambulatory, blood pressure measurement is more predictive of target organ damage than resting measures. Since the primary purpose of lowering blood pressure is to reduce cardiovascular target organ damage, 24-hour ambulatory measures may be more valid. Unfortunately, to date, only three published physical training studies (Gilders, Voner, & Dudley, 1989; Seals & Reiling, 1991; Van Hoof et al., 1989), all leading to conflicting results, have been conducted using this alternative method.

Relationships Between Changes and Physical Characteristics

The purpose of the first section of this subdivision was to report the relationships between aerobic exercise-related changes in resting blood pressure and selected physical characteristics: age, initial weight, weight changes, initial percent fat, percent fat changes, and initial blood pressure levels. The second portion of this subdivision discussed the reported relationships between exercise-induced changes in resting blood pressure and selected physical characteristics.

Results

The relationships between physical characteristics of subjects and exercise-induced effect-size changes in resting blood pressure may be found in Table 10. As can be seen, the correlations between age and effect-size changes were: *r* = - 0.171 for resting systolic pressure and *r* = -0.352 for resting diastolic pressure. Neither one of these relationships was significant.

For initial body weight, resting systolic blood pressure effect-size changes yielded a nonsignificant correlation of *r* = -0.131. Resting diastolic blood pressure produced a correlation coefficient of *r* = 0.040. None of these associations were statistically significant.

There was a statistically significant relationship between changes in body weight and effect-size changes in resting systolic blood pressure (*r* = -0.582). Resting diastolic blood pressure yielded a correlation of *r* = -0.179. This association was not statistically significant.

Initial percent body fat was positively correlated with effect-size changes for resting systolic blood pressure and diastolic blood pressure. Resting systolic blood pressure yielded a correlation of *r* = 0.904. The correlation for resting diastolic blood pressure was *r* = 0.707.

There was also a statistically significant and positive association between changes in percent body fat and

Table 10

Analysis of Data for Physical Characteristics

Correlations with effect-size changes

Characteristic	Pearson product correlations N^a	(r)
Systolic		
Age (yrs)	21	-0.171
Initial weight (kg)	27	-0.131
Weight changes (kg)	26	-0.582*
Initial fat (%)	8	0.904*
Fat changes (%)	8	0.857*
Initial blood pressure levels	41	0.092
Diastolic		
Age (yrs)	19	-0.352
Initial weight (kg)	24	0.040
Weight changes (kg)	23	-0.179
Initial fat (%)	8	0.707*
Fat changes (%)	8	0.652
Initial blood pressure levels	33	0.343

[a]N = number of groups reporting data.

*Statistically significant at $p < .05$.

exercise-induced effect-size reductions in resting systolic blood pressure. The correlation for resting systolic blood pressure was r = .857. For resting diastolic blood pressure, a nonsignificant correlation of r = .652 was exhibited.

Initial resting blood pressure levels and exercise-induced changes in resting blood pressure did not demonstrate any statistically significant relationship. The correlation for resting systolic blood pressure was r = 0.092. Resting diastolic blood pressure yielded a correlation coefficient of r = 0.343.

Discussion

The relationships between exercise-induced effect-size changes in resting blood pressure and selected physical characteristics of hypertensive adults resulted in some notable findings. First of all, the lack of association between age and exercise-induced changes in resting blood pressure is in opposition to conclusions drawn in narrative reviews by Tipton (1984, 1991). In Tipton's reviews, it was concluded that the beneficial effects of exercise on resting blood pressure were best demonstrated in older subjects. One possible explanation for the discrepancy in results may be the methods used in arriving at these conclusions. This review's conclusions were the derivative of quantitative analysis. Tipton's conclusions were based on subjective observation of study results.

Despite the fact that none of the results examining the relationship between age and aerobic exercise-induced blood pressure changes in hypertensive adults were significant, it is interesting to note that both of these correlations point in the direction which would suggest that as one ages, the beneficial effects of aerobic exercise on resting systolic and diastolic blood pressure declines. This possible association would also appear to be greater in resting diastolic blood pressure. According to Harris (1975), as one ages, blood pressure rises as a result of a loss of elasticity in the walls of larger arteries and an increased role of the nervous system. While it is not the purpose of this study to dwell on the mechanisms involved in this phenomena, it may be that cardiac changes which occur with age inhibit exercise-induced reductions on resting blood pressure in older hypertensive adults.

The lack of association between initial body weight and exercise-related reductions in both resting systolic and diastolic blood pressure in hypertensive adults conflicts with previous reviews on this topic. For example, Tipton (1984, 1991) concluded that heavier individuals displayed greater reductions in resting blood pressure as a result of aerobic exercise. Again, one of the possible reasons for the discrepancies in conclusions between the two reviews may be related to the method of analysis used by the investigators. Tipton's (1984, 1991) conclusions were drawn from subjective observation of study results. These studies' conclusions were based on quantitative analysis.

The statistically significant negative correlation between changes in body weight and reductions in resting systolic blood pressure suggests that reductions in resting systolic blood pressure were greater in individuals who lost less body weight during the training program. While not statistically significant, changes in resting diastolic blood pressure were also negatively correlated with changes in body weight. The results of this meta-analytic study contrast with the findings of Boyer and Kasch (1970) and Cade et al. (1984), who found no relationship between changes in body weight and changes in resting blood pressure levels. One possible rationale for the discrepant results may be the generality of body weight. It may be more relevant to focus on the composition of body weight, specifically, fat-free weight.

One of the most significant findings of this investigation was the strong positive correlation between initial percent body fat and exercise-related changes in resting systolic and diastolic blood pressure. It appears that hypertensive adults with higher initial percent fat levels experience greater reductions in resting systolic and diastolic blood pressure as a result of aerobic exercise. This coincides with Tipton's (1991) review in which he concluded that normotensive individuals who were fatter experienced greater reductions in blood pressure from physical training. The results of this meta-analytic study suggest that this is also true for hypertensive adults. Initial percent fat levels seem to be a more important variable than initial body weight.

Another significant finding of this study was the strong positive correlation between changes in percent body fat and exercise-induced changes in resting systolic blood pressure. The results indicated that the greater the reduction in percent body fat, the greater the reduction in resting systolic blood pressure levels as a result of aerobic exercise. This is in opposition to the observations of Cade et al. (1984), who reported that changes in percent body fat were not related to changes in resting blood pressure levels. In addition, while the results for resting diastolic blood pressure were not statistically significant, there was the potential for a strong positive correlation similar to that for systolic pressure. Since it is well-established that a clear relationship exists between obesity and high blood pressure, it would seem appropriate that decreases in percent fat levels would be associated with exercise-induced decreases in resting systolic and diastolic blood pressure.

In this investigation, initial resting blood pressure levels and exercise-induced changes in resting blood pressure were not significantly correlated. However, while these results were not statistically significant, they did tend to indicate that higher initial levels of resting blood pressure were associated with larger absolute exercise-related decreases in both resting systolic and diastolic blood pressure. The potential for this association appears to be especially true for resting diastolic blood pressure.

The results of this investigation should be viewed within the perspective that independent variables in a meta-analysis are not identically distributed. Thus, low correlation coefficients may still indicate strong relationships.

Relationships Between Changes and Training Programs

The first part of this section reported the relationships between aerobic exercise-induced changes on resting blood pressure and training program characteristics: length, frequency, intensity, and duration. The second portion of this section discussed the reported findings on relationships between aerobic exercise-related changes and training program characteristics.

Results

The relationships between training programs and effect-size changes in resting blood pressure are presented in Table 11. No statistically significant relationships between the length of training in weeks and exercise-induced effect-size changes in resting systolic or diastolic blood pressure were observed. Resting systolic blood pressure

Table 11

Analysis of Data for Training Programs

Correlations with effect-size changes

Characteristic	Pearson product correlations	
	N[a]	(r)
Systolic		
Length (weeks)	41	-0.036
Frequency (days/week)	39	-0.038
Intensity (% MHR)[b]	24	-0.124
Duration (minutes/session)	38	-0.888
Diastolic		
Length (weeks)	33	-0.179
Frequency (days/week)	31	-0.168
Intensity (% MHR)[b]	22	-0.224
Duration (minutes/session)	32	-0.177

[a]N = number of groups reporting data.

[b]% MHR = percent maximum heart rate.

produced a correlation of r = -0.036. Resting diastolic blood pressure produced a correlation of r = -0.179. Neither of these negative correlations was significant.

The frequency of training in days per week was not significantly correlated with exercise-induced effect-size changes in resting blood pressure. Resting systolic blood pressure produced an r value of -0.038. For resting diastolic blood pressure, the correlation was r = -0.168. None of these measures were significant.

Intensity of training, expressed as a percentage of maximum heart rate, was not significantly associated with exercise-induced effect-size changes in resting systolic or diastolic blood pressure levels. Resting systolic blood pressure yielded a nonsignificant r value of -0.124. For resting diastolic blood pressure, there was a correlation of r = -0.224.

The minutes-per-session that subjects trained were not significantly associated with effect-size changes in blood pressure as a result of aerobic exercise. Negative correlations of r = -0.088 and r = -0.177 were produced for systolic and diastolic blood pressure, respectively. None of these changes were statistically significant.

Discussion

Taken collectively as a group, the results of this investigation demonstrated no statistically significant relationship between components of the training program and aerobic exercise-induced effect-size changes on resting blood pressure in hypertensive adults. However, it was interesting to note that all of the correlation coefficients were negative. Since the independent variables in a meta-analysis are not identically distributed, correlations that were low may still indicate a strong relationship. Thus, the negative correlations observed in this investigation may suggest that less work is associated with greater reductions in resting systolic and diastolic blood pressure levels. This would support the findings of Roman et al. (1981), who found that when the intensity of exercise was increased above 70 percent of maximum heart rate, reductions in resting systolic and diastolic blood pressure were no longer observed. One of the postulated mechanisms for the lowering of blood pressure is the reduction in sympathetic activity which has been observed with certain exercise training. This exercise-induced reduction in sympathetic activity has been associated with lower levels of norepinephrine (Duncan et al., 1985). However, the intensity of exercise may dictate whether or not reductions in norepinephrine levels will occur. Jost, Weiss, and Weicker (1990) recently showed that high intensity exercise increased the ratio of norepinephrine to epinephrine, while low-intensity exercise decreased the ratio of norepinephrine to epinephrine. It appears that lower intensity exercise may be more beneficial in the reduction of resting blood pressure in hypertensive adults. Since the average intensity of training in this study was approximately 73 percent of maximum heart rate, it would seem that the American College of Sports Medicine's Guidelines (1991) are not entirely appropriate for reducing resting blood pressure in hypertensive adults. Instead of the recommended intensity level of 55 to 90 percent of maximal heart rate, lower intensities may be necessary in order to reduce resting blood pressure levels in hypertensive adults. Consequently, increases in maximum oxygen consumption (considered to be a component of fitness) may not be related to decreases on resting blood pressure in hypertensive adults. A study by Roman et al. (1981) has shown that decreases in resting blood pressure as a result of exercise were not closely related to increases in maximum oxygen consumption. It appears that other components of fitness, particularly decreases in body fat, may be more closely associated with exercise-induced decreases in resting blood pressure in hypertensive adults. Since decreases in body fat are directly related to energy expenditure, it would seem appropriate to accept Gordon et al.'s (1990) recommendation that exercise programs for hypertensive adults should be based primarily on energy expenditure. Since it appears that higher intensity levels would attenuate aerobic exercise-induced reductions in resting blood pressure, adequate energy expenditure may have to be derived from an increase in the frequency and/or duration of activity.

The results of this investigation (see Table 3) suggest that adequate reductions in resting blood pressure may be accomplished by training at a frequency of three times per week for a duration of 50 minutes per session. The training intensity should be equivalent to approximately 70 percent of maximal heart rate. Additionally, it appears that the magnitude of reduction in resting blood pressure is greatest during the first 12 weeks of aerobic exercise training. However, these training programs must be continued in order for reductions in resting blood pressure to be maintained. Studies by Cade et al. (1984), Filipovsky et al. (1991), and Roman et al. (1981) have shown significant increases in resting blood pressure levels upon cessation of aerobic exercise training.

CHAPTER 5

Summary, Conclusions, Recommendations, and Implications

Summary

The purpose of this study was to examine the effects of aerobic exercise on resting systolic and diastolic blood pressure in hypertensive adults. The results of 30 longitudinal studies published in English and conducted over the past 25 years were statistically aggregated using meta-analytic techniques.

Using *t*-distribution analysis, statistically significant effect-size differences ($p < .05$) were found for resting systolic and diastolic blood pressure in all exercise groups. None of the changes were significant for the controls. One-way analysis of variance on effect-size differences across different categories of resting blood pressure revealed no statistically significant differences.

Pearson-product moment correlations comparing exercise-induced effect-size changes and selected variables revealed statistically significant relationships ($p < .05$) for body-weight changes, initial percent fat levels, and percent fat changes. These associations were significant for resting systolic blood pressure only.

Conclusions

Based on the results of this study, it was concluded that lower extremity aerobic activity may be used as a separate nonpharmacological therapy in individuals with mild hypertension. For people with moderate and severe hypertension, aerobic exercise may serve as an adjuvant to pharmacological and/or other nonpharmacological therapies.

Recommendations for Future Experimental Research

While the primary objective of meta-analytic research is to summarize the results of studies, it is also necessary to identify weaknesses and provide directions for future research. Overall, the experimental research dealing with aerobic exercise-induced effects on resting blood pressure had many imperfections. For example, the ability to analyze data according to gender was not possible in this investigation. While 50 percent of the studies analyzed used females as subjects, only 9 percent reported data partitioned by gender. Future experimental research needs to examine and include data partitioned by gender.

It has been reported that Blacks, Puerto Ricans, Cubans, and Mexican-Americans are more likely to suffer from high blood pressure than Anglo-Americans (American Heart Association, 1989). Since none of the studies in this investigation reported data according to race, future experimental research should examine how different hypertensives, partitioned by ethnic status, respond to aerobic exercise as a hypotensive therapy.

In addition, this study was unable to ascertain the effects of medication on aerobic exercise-induced changes on resting blood pressure in hypertensive adults. Only 6 percent of the studies in this meta-analysis provided adequate data partitioned by medication status. Future studies need to address the interaction between pharmacological, as well as other nonpharmacological, therapies (stress relaxation techniques, diet, etc.) and exercise-related changes on blood pressure in hypertensive adults.

The experimental design of many of the studies lacked significant components. One of the most outstanding weaknesses of these studies was the lack of hypertensive control groups. Of the studies chosen for this meta-analysis, only 34 percent included a hypertensive control group. Future experimental research needs to include hypertensive control groups in their investigations.

Additionally, only 28 percent of the studies provided adequate information on percent fat levels, a potentially confounding variable. Forty-one percent of the studies lacked appropriate data on the intensity of their training programs. Future research should include complete data on the physical characteristics of their subjects (age; race; gender; diet; medication status; and pre- and post-measures of height, body weight, percent fat, and maximum oxygen consumption); characteristics of the training programs (length of training, frequency, intensity, duration, and mode); and blood pressure measurement conditions (type, position, and number of measurements). For this latter component, it appears that the use of 24-hour ambulatory blood pressure measurements may be more valid than traditional resting blood pressure measures in establishing the significance of aerobic-exercise programs for reducing blood pressure levels (Devereux & Pickering, 1988; Seals & Reiling, 1991).

Implications for Teaching

There exists a paucity of information in exercise physiology textbooks (deVries, 1986; Fox et al., 1989; Noble, 1986; Powers & Howley, 1990) concerning the aerobic exercise-induced effects on resting blood pressure in hypertensive adults. Increased knowledge on this topic will allow exercise physiology instructors to better equip our future physical education and fitness/wellness professionals with the knowledge necessary for educating others.

Based on the results of this meta-analytic review, the following information may be taught. A numbered format was provided in order to ease the extraction of information for the purpose of developing a lesson plan on this topic.

1. Aerobic exercise reduces resting systolic blood pressure by approximately 12 mmHg (8 percent) in hypertensive adults.

2. Aerobic exercise reduces resting diastolic blood pressure by approximately 9 mmHg (9 percent) in hypertensive adults.

3. Aerobic exercise reduces resting systolic blood pressure by approximately 9 mmHg (6 percent) in mild hypertensive adults.

4. Aerobic exercise reduces resting systolic blood pressure by approximately 15 mmHg (10 percent) in moderately hypertensive adults.

5. Aerobic exercise reduces resting systolic blood pressure by approximately 16 mmHg (10 percent) in severely hypertensive adults.

6. Aerobic exercise reduces resting diastolic blood pressure by approximately 9 mmHg (9 percent) in mild hypertensive adults.

7. Aerobic exercise reduces resting diastolic blood pressure by approximately 8 mmHg (8 percent) in moderately hypertensive adults.

8. Aerobic exercise reduces resting diastolic blood pressure by approximately 11 mmHg (11 percent) in severely hypertensive adults.

9. Aerobic exercise as a separate therapy normalizes resting systolic blood pressure in mild hypertensive adults.

10. Aerobic exercise as a separate therapy normalizes resting diastolic blood pressure in mild hypertensive adults.

11. Aerobic exercise as a separate therapy is not sufficient for the normalization of resting systolic blood pressure in moderately hypertensive adults.

12. Aerobic exercise as a separate therapy is not sufficient for the normalization of resting diastolic blood pressure in moderately hypertensive adults.

13. Aerobic exercise as a separate therapy is not sufficient for the normalization of resting systolic blood pressure in severely hypertensive adults. Other nonpharmacological and/or pharmacological therapies are necessary.

14. Aerobic exercise as a separate therapy is not sufficient for the normalization of resting diastolic blood pressure in severely hypertensive adults. Other nonpharmacological and/or pharmacological therapies are necessary.

15. No relationship exists between initial blood pressure levels and aerobic exercise-induced changes on resting systolic blood pressure in hypertensive adults.

16. No relationship exists between initial blood pressure levels and aerobic exercise-induced changes on resting diastolic blood pressure in hypertensive adults.

17. No relationship exists between age and aerobic exercise-induced reductions on resting systolic blood pressure in hypertensive adults.

18. No relationship exists between age and aerobic exercise-induced reductions on resting diastolic blood pressure in hypertensive adults.

19. No relationship exists between initial body weight and aerobic exercise-induced changes on resting systolic blood pressure in hypertensive adults.

20. No relationship exists between initial body weight and aerobic exercise-induced changes on resting diastolic blood pressure in hypertensive adults.

21. The greater the reductions in body weight, the greater the aerobic exercise-induced reductions on resting systolic blood pressure in hypertensive adults.

22. No relationship exists between changes in body weight and aerobic exercise-induced reductions on resting diastolic blood pressure in hypertensive adults.

23. The greater the initial percent body fat levels of the person, the greater the aerobic exercise-induced reductions on resting systolic blood pressure in hypertensive adults.

24. The greater the initial percent body-fat levels, the greater the aerobic exercise-induced reductions on resting diastolic blood pressure in hypertensive adults.

25. The greater the reductions in percent body fat, the greater the aerobic exercise-induced reductions on resting systolic blood pressure in hypertensive adults.

26. No relationship exists between changes in percent body fat and aerobic exercise-induced reductions on resting diastolic blood pressure in hypertensive adults.

27. No relationship exists between length of training and aerobic exercise-induced changes on resting systolic blood pressure in hypertensive adults.

28. No relationship exists between length of training and aerobic exercise-induced changes on resting diastolic blood pressure in hypertensive adults.

29. No relationship exists between frequency of training and aerobic exercise-induced changes on resting systolic blood pressure in hypertensive adults.

30. No relationship exists between frequency of training aerobic exercise-induced changes on resting diastolic blood pressure in hypertensive adults.

31. No relationship exists between intensity of training and aerobic exercise-induced changes on resting systolic blood pressure in hypertensive adults.

32. No relationship exists between intensity of training and aerobic exercise-induced changes on resting diastolic blood pressure in hypertensive adults.

33. No relationship exists between duration of training and aerobic exercise-induced changes on resting systolic blood pressure in hypertensive adults.

34. No relationship exists between duration of training and aerobic exercise-induced reductions on resting diastolic blood pressure in hypertensive adults.

35. Hypertensive adults can reduce resting systolic and diastolic blood pressure levels by participating in

aerobic exercise approximately three times per week, for a duration of 50 minutes per session, at 70 percent of their maximal heart rate.

36. The greatest aerobic exercise-induced reductions on both resting systolic and diastolic blood pressure in hypertensive adults occurs after approximately 12 weeks of training.

APPENDICES

APPENDIX A

STUDIES USED IN META-ANALYSIS

APPENDIX A

STUDIES USED IN META-ANALYSIS

Attina, D. A., Giuliano, G., Arcangeli, G., Musante, R., & Cupelli, V. (1986). Effects of one year of physical training on borderline hypertension: An evaluation of bicycle ergometer exercise testing. Journal of Cardiovascular Pharmacology, 8(Suppl. 5), S145-S147.

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APPENDIX B

CODING SHEETS

APPENDIX B

CODING SHEETS

Physical Characteristics for Systolic Exercise Studies

Study	Age (yrs)	Sex	Height (cm)	Weight (kg) pre	Weight (kg) post	Fat (%) pre	Fat (%) post
Attina et al. (1986)	36	M	NA	NA	NA	NA	NA
Attina et al. (1986)	36	M	NA	NA	NA	NA	NA
Baglivo et al. (1990)	49	MF	NA	78	78	NA	NA
Barry et al. (1966)	35-78	MF	NA	73	73	NA	NA
Bonanno & Lies (1974)	33-58	M	NA	85	NA	NA	NA
Boyer & Kasch (1970)	35-61	M	NA	NA	NA	NA	NA
Cade et al. (1984)	39	MF	NA	NA	NA	29	27
Cade et al. (1984)	44	MF	NA	NA	NA	29	27
Cade et al. (1984)	NA	MF	NA	NA	NA	29	27
Cade et al. (1984)	35	MF	NA	NA	NA	29	27
Cleroux et al. (1987)	37	MF	170	76	75	NA	NA
Cleroux et al. (1987)	32	MF	178	86	83	NA	NA
De Plaen & Detry (1980)	47	MF	NA	77	75	NA	NA
deVries (1970)	52-88	M	NA	75	74	21	20
Duncan et al. (1985)	21-37	M	NA	85	85	NA	NA
Filipovsky et al. (1991)	54	MF	NA	NA	NA	NA	NA
Gleichmann et al. (1989)	43-73	NA	NA	74	73	NA	NA
Hagberg et al. (1989)	65	MF	NA	79	77	25	24
Hagberg et al. (1989)	64	MF	NA	69	68	21	21
Hanson & Nedde (1970)	30-54	M	NA	NA	NA	NA	NA
Hanson & Nedde (1970)	30-54	M	NA	NA	NA	NA	NA
Jo et al. (1989)	43	M	NA	66	66	NA	NA

Physical Characteristics for Systolic Exercise Studies (continued)

Study	Age (yrs)	Sex	Height (cm)	Weight (kg) pre	Weight (kg) post	Fat (%) pre	Fat (%) post
Johnson & Grover (1967)	NA	NA	NA	NA	NA	NA	NA
Kinoshita et al. (1988)	32-60	MF	NA	58	58	NA	NA
Kinoshita et al. (1988)	32-60	MF	NA	70	70	NA	NA
Kiyonaga et al. (1985)	46	MF	NA	65	63	NA	NA
Kukkonen et al. (1982)	35-50	M	176	78	77	NA	NA
Nelson et al. (1986)	44	MF	NA	74	74	NA	NA
Nomura et al. (1984)	25-52	M	NA	66	64	NA	NA
Nomura et al. (1984)	25-52	M	NA	65	63	NA	NA
Painter et al. (1986)	42	MF	NA	NA	NA	NA	NA
Ressl et al. (1977)	38-53	M	NA	83	80	NA	NA
Roman et al. (1981)	NA	F	NA	NA	NA	NA	NA
Rudd & Day (1967)	49	M	NA	NA	NA	NA	NA
Seals & Reiling (1991)	61	MF	172	76	76	25	25
Tanabe et al. (1988)	51	M	NA	70	70	NA	NA
Tanabe et al. (1988)	51	F	NA	53	53	NA	NA
Urata et al. (1987)	32-60	MF	158	62	62	NA	NA
Weber et al. (1983)	60-80	M	NA	71	69	NA	NA
Weber et al. (1983)	60-80	F	NA	64	62	NA	NA
Wilmore et al. (1970)	53	M	NA	77	76	NA	NA

Note: NA = not available.

Blood Pressure Results for Systolic Exercise Studies

Study	N	Pre (mmhg)	Post (mmHg)	SD (pre)	Dif. (pre-post)
Attina et al. (1986)	14	141	136	10	5
Attina et al. (1986)	12	143	144	8	1
Baglivo et al. (1990)	15	155	136	10	19
Barry et al. (1966)	8	147	127	21	20
Bonanno & Lies (1974)	12	148	135	18	13
Boyer & Kasch (1970)	23	159	146	14	13
Cade et al. (1984)	58	150	135	6	15
Cade et al. (1984)	23	165	135	14	30
Cade et al. (1984)	16	163	131	10	32
Cade et al. (1984)	7	172	141	14	31
Cleroux et al. (1987)	7	145	135	8	10
Cleroux et al. (1987)	5	140	135	10	5
De Plaen & Detry (1980)	5	162	158	26	4
deVries (1970)	66	140	136	21	4
Duncan et al. (1985)	44	148	134	6	14
Filipovsky et al. (1991)	77	157	142	20	15
Gleichmann et al. (1989)	29	153	139	18	14
Hagberg et al. (1989)	11	158	151	21	7
Hagberg et al. (1989)	8	160	154	18	6
Hanson & Nedde (1970)	8	170	137	19	33
Hanson & Nedde (1970)	5	150	135	19	15
Jo et al. (1989)	14	147	136	17	11
Johnson & Grover (1967)	4	185	195	31	-10
Kinoshita et al. (1988)	12	153	134	15	19
Kinoshita et al. (1988)	9	157	150	7	7
Kiyonaga et al. (1985)	9	157	136	12	21

Blood Pressure Results for Systolic Exercise Studies (continued)

Study	N	Pre (mmhg)	Post (mmHg)	SD (pre)	Dif. (pre-post)
Kukkonen et al. (1982)	13	142	146	10	- 4
Nelson et al. (1986)	13	149	138	9	11
Nomura et al. (1984)	7	141	135	6	6
Nomura et al. (1984)	14	141	130	18	11
Painter et al. (1986)	13	152	138	34	14
Ressl et al. (1977)	10	182	192	14	-10
Roman et al. (1981)	24	182	161	16	20
Rudd & Day (1967)	19	155	133	12	22
Seals & Reiling (1991)	14	146	138	7	8
Tanabe et al. (1988)	13	147	139	15	8
Tanabe et al. (1988)	11	156	139	15	17
Urata et al. (1987)	10	153	144	12	9
Weber et al. (1983)	43	146	132	26	14
Weber et al. (1983)	27	141	132	21	9
Wilmore et al. (1970)	7	140	125	14	15

Exercise Programs for Systolic Exercise Studies

Study	Length (weeks)	Freq. (dys/wk)	Int. (% MHR)	Dur. (min.)	Mode
Attina et al. (1986)	52	3	NA	NA	Comb
Attina et al. (1986)	5	3	NA	NA	Comb
Baglivo et al. (1990)	12	3	NA	50	Comb
Barry et al. (1966)	12	3	NA	40	Cycle
Bonanno & Lies (1974)	12	3	70-85	40-55	Jog
Boyer & Kasch (1970)	23	3	70	40-50	Jog
Cade et al. (1984)	12	3	NA	40	Walk
Cade et al. (1984)	12	3	NA	40	Walk
Cade et al. (1984)	12	3	NA	40	Walk
Cade et al. (1984)	12	3	NA	40	Walk
Cleroux et al. (1987)	20	3	72:	20-45	Cycle
Cleroux et al. (1987)	20	3	72:	20-45	Jog
De Plaen & Detry (1980)	12	3	72-79:	60	Comb
deVries (1970)	7	3	NA	30-40	Jog
Duncan et al. (1985)	16	3	70-80	60	Jog
Filipovsky et al. (1991)	5	3	70	30	Cycle
Gleichmann et al. (1989)	56	NA	NA	180-210	Comb
Hagberg et al. (1989)	37	3	65:	60	Comb
Hagberg et al. (1989)	37	3	79-91:	60	Comb
Hanson & Nedde (1970)	28	3	NA	60	Comb
Hanson & Nedde (1970)	28	3	NA	60	Comb
Jo et al. (1989)	12	2	65	60	Comb
Johnson & Grover (1967)	10	3	NA	35	Jog
Kinoshita et al. (1988)	10	3	58-72:	70	Cycle
Kinoshita et al. (1988)	10	3	58-72:	70	Cycle
Kiyonaga et al. (1985)	10	3	65:	60	Cycle

Exercise Programs for Systolic Exercise Studies (continued)

Study	Length (weeks)	Freq. (dys/wk)	Int. (% MHR)	Dur. (min.)	Mode
Kukkonen et al. (1982)	16	3	66	50	Cycle
Nelson et al. (1986)	4	3	72-79	30	Cycle
Nomura et al. (1984)	3	20	83:	9	Cycle
Nomura et al. (1984)	3	20	83:	9	Cycle
Painter et al. (1986)	24	3-4	83-91:	30-45	Cycle
Ressl et al. (1977)	4	5	NA	36	Cycle
Roman et al. (1981)	12	3	NA	NA	Comb
Rudd & Day (1967)	22	NA	NA	60	Jog
Seals & Reiling (1991)	24	3	58-65	30	Walk
Tanabe et al. (1988)	10	3	65:	70	Cycle
Tanabe et al. (1988)	10	3	65:	70	Cycle
Urata et al. (1987)	10	3	100	65	Cycle
Weber et al. (1983)	4	15	70-80	140	Jog
Weber et al. (1983)	4	15	70-80	140	Jog
Wilmore et al. (1970)	10	3	NA	12-24	Jog

Notes: NA = data were not available. : = values were estimated from conversion table developed by Howley and Franks (cited in Powers & Howley, 1990).

Physical Characteristics For Systolic Control Studies

Study	Age (yrs)	Sex	Height (cm)	Weight (kg) pre	Weight (kg) post	Fat (%) pre	Fat (%) post
Baglivo et al. (1990)	51	MF	NA	79	79	NA	NA
Barry et al. (1966)	58-83	MF	NA	91	NA	NA	NA
Bonanno & Lies (1974)	30-53	M	NA	NA	NA	NA	NA
De Plaen & Detry (1980)	47	MF	NA	NA	NA	NA	NA
deVries (1970)	52-88	M	NA	71	71	20	20
Duncan et al. (1985)	21-37	M	NA	90	91	NA	NA
Kukkonen et al. (1982)	35-50	M	176	75	74	NA	NA
Nelson et al. (1986)	44	MF	NA	74	74	NA	NA
Seals & Reiling (1991)	61	MF	176	76	76	22	22
Urata et al. (1987)	32-60	MF	157	60	59	NA	NA

Note: NA = not available.

Blood Pressure Results for Systolic Control Studies

Study	N	Pre (mmhg)	Post (mmHg)	SD (pre)	Dif. (pre-post)
Baglivo et al. (1990)	17	155	142	4	13
Barry et al. (1966)	5	152	156	32	- 4
Bonanno & Lies (1974)	15	150	147	16	3
De Plaen & Detry (1980)	4	158	154	22	4
deVries (1970)	32	140	141	23	- 1
Duncan et al. (1985)	12	145	139	5	6
Kukkonen et al. (1982)	12	142	138	10	4
Nelson et al. (1986)	13	149	143	7	6
Seals & Reiling (1991)	12	147	140	10	7
Urata et al. (1987)	10	153	144	12	9

Physical Characteristics for Diastolic Exercise Studies

Study	Age (yrs)	Sex	Height (cm)	Weight (kg) pre	Weight (kg) post	Fat (%) pre	Fat (%) post
Baglivo et al. (1990)	49	MF	NA	78	78	NA	NA
Bonanno & Lies (1974)	33-58	M	NA	85	NA	NA	NA
Boyer & Kasch (1970)	35-61	M	NA	NA	NA	NA	NA
Cade et al. (1984)	39	MF	NA	NA	NA	29	27
Cade et al. (1984)	44	MF	NA	NA	NA	29	27
Cade et al. (1984)	NA	MF	NA	NA	NA	29	27
Cade et al. (1984)	35	MF	NA	NA	NA	29	27
Choquette & Ferguson (1973)	42	M	176	82	82	NA	NA
Cleroux et al. (1987)	37	MF	170	76	75	NA	NA
Cleroux et al. (1987)	32	MF	178	86	83	NA	NA
De Plaen & Detry (1980)	47	MF	NA	77	75	NA	NA
Duncan et al. (1985)	21-37	M	NA	85	85	NA	NA
Filipovsky et al. (1991)	54	MF	NA	NA	NA	NA	NA
Gleichmann et al. (1989)	43-73	NA	NA	74	73	NA	NA
Hagberg et al. (1989)	65	MF	NA	79	77	25	24
Hagberg et al. (1989)	64	MF	NA	69	68	21	21
Hanson & Nedde (1970)	30-54	M	NA	NA	NA	NA	NA
Jo et al. (1989)	43	M	NA	66	66	NA	NA
Kinoshita et al. (1988)	32-60	MF	NA	58	58	NA	NA
Kinoshita et al. (1988)	32-60	MF	NA	70	70	NA	NA
Kiyonaga et al. (1985)	46	MF	NA	65	63	NA	NA
Kukkonen et al. (1982)	35-50	M	176	78	77	NA	NA
Martin et al. (1990)	44	M	NA	90	90	29	29
Nelson et al. (1986)	44	MF	NA	74	74	NA	NA

Physical Characteristics for Diastolic Exercise Studies (continued)

Study	Age (yrs)	Sex	Height (cm)	Weight (kg) pre	Weight (kg) post	Fat (%) pre	Fat (%) post
Nomura et al. (1984)	25-52	M	NA	66	64	NA	NA
Nomura et al. (1984)	25-52	M	NA	65	63	NA	NA
Ressl et al. (1977)	38-53	M	NA	83	80	NA	NA
Roman et al. (1981)	NA	F	NA	NA	NA	NA	NA
Rudd & Day (1967)	49	M	NA	NA	NA	NA	NA
Seals & Reiling (1991)	61	MF	172	76	76	25	25
Tanabe et al. (1988)	51	M	NA	70	70	NA	NA
Tanabe et al. (1988)	51	F	NA	53	53	NA	NA
Urata et al. (1987)	32-60	MF	158	62	62	NA	NA

Note: NA = not available.

Blood Pressure Results for Diastolic Exercise Studies

Study	N	Pre (mmhg)	Post (mmHg)	SD (pre)	Dif. (pre-post)
Baglivo et al. (1990)	15	101	87	3	14
Bonanno & Lies (1974)	12	97	83	8	14
Boyer & Kasch (1970)	23	105	93	14	12
Cade et al. (1984)	58	95	83	3	12
Cade et al. (1984)	23	110	89	9	21
Cade et al. (1984)	16	108	84	4	24
Cade et al. (1984)	7	114	95	5	19
Choquette & Ferguson (1973)	37	90	82	7	8
Cleroux et al. (1987)	7	98	90	4	8
Cleroux et al. (1987)	5	95	90	6	5
De Plaen & Detry (1980)	5	104	104	14	0
Duncan et al. (1985)	44	94	87	6	7
Filipovsky et al. (1991)	77	98	89	10	9
Gleichmann et al. (1989)	29	93	87	11	6
Hagberg et al. (1989)	11	90	87	10	3
Hagberg et al. (1989)	8	100	91	10	9
Hanson & Nedde (1970)	8	90	77	16	13
Jo et al. (1989)	14	98	90	7	8
Kinoshita et al. (1988)	12	97	85	6	12
Kinoshita et al. (1988)	9	105	105	11	0
Kiyonaga et al. (1985)	9	104	90	3	14
Kukkonen et al. (1982)	13	103	99	7	4
Martin et al. (1990)	10	95	85	4	10
Nelson et al. (1986)	13	99	90	8	9
Nomura et al. (1984)	7	98	89	10	9
Nomura et al. (1984)	14	93	85	14	8

Blood Pressure Results for Diastolic Exercise Studies (continued)

Study	N	Pre (mmhg)	Post (mmHg)	SD (pre)	Dif. (pre-post)
Ressl et al. (1977)	10	99	98	9	1
Roman et al. (1981)	24	110	97	10	18
Rudd & Day (1967)	19	95	85	10	10
Seals & Reiling (1991)	14	94	87	4	7
Tanabe et al. (1988)	13	99	95	9	4
Tanabe et al. (1988)	11	98	91	9	7
Urata et al. (1987)	10	103	98	12	5

Exercise Programs for Diastolic Exercise Studies

Study	Length (weeks)	Freq. (dys/wk)	Int. (% MHR)	Dur. (min.)	Mode
Baglivo et al. (1990)	12	3	NA	50	Comb
Bonanno & Lies (1974)	12	3	70-85	40-55	Jog
Boyer & Kasch (1970)	24	2	70	40-50	Jog
Cade et al. (1984)	12	3	NA	40	Walk
Cade et al. (1984)	12	3	NA	40	Walk
Cade et al. (1984)	12	3	NA	40	Walk
Cade et al. (1984)	12	3	NA	40	Walk
Choquette & Ferguson (1973)	24	7	NA	10-60	Jog
Cleroux et al. (1987)	20	3	72:	20-45	Cycle
Cleroux et al. (1987)	20	3	72:	20-45	Jog
De Plaen & Detry (1980)	12	3	72-79:	60	Comb
Duncan et al. (1985)	16	3	70-80	60	Jog
Filipovsky et al. (1991)	5	3	70	30	Cycle
Gleichmann et al. (1989)	56	NA	NA	180-210	Comb
Hagberg et al. (1989)	37	3	65:	60	Comb
Hagberg et al. (1989)	37	3	79-91:	60	Comb
Hanson & Nedde (1970)	28	3	NA	60	Comb
Jo et al. (1989)	12	2	65:	60	Comb
Kinoshita et al. (1988)	10	3	58-72:	70	Cycle
Kinoshita et al. (1988)	10	3	58-72:	70	Cycle
Kiyonaga et al. (1985)	10	3	65:	60	Cycle
Kukkonen et al. (1982)	16	3	66	50	Cycle
Martin et al. (1990)	10	4	65-80	30	Comb
Nelson et al. (1986)	4	3	72-79	45	Cycle
Nomura et al. (1984)	3	20	83:	9	Cycle
Nomura et al. (1984)	3	20	83:	9	Cycle

Exercise Programs for Diastolic Exercise Studies (continued)

Study	Length (weeks)	Freq. (dys/wk)	Int. (% MHR)	Dur. (min.)	Mode
Ressl et al. (1977)	4	5	NA	36	Cycle
Roman et al. (1981)	12	3	NA	NA	Comb
Rudd & Day (1967)	22	NA	NA	60	Jog
Seals & Reiling (1991)	24	3	58-65	30	Walk
Tanabe et al. (1988)	10	3	65:	70	Cycle
Tanabe et al. (1988)	10	3	65:	70	Cycle
Urata et al. (1987)	10	3	100	65	Cycle

Notes: NA = not available. : = values were estimated from conversion table developed by Howley and Franks (cited in Powers & Howley, 1990).

Physical Characteristics For Diastolic Control Studies

Study	Age (yrs)	Sex	Height (cm)	Weight (kg) pre	Weight (kg) post	Fat (%) pre	Fat (%) post
Baglivo et al. (1990)	51	MF	NA	79	79	NA	NA
Bonanno & Lies (1974)	30-53	M	NA	NA	NA	NA	NA
De Plaen & Detry (1980)	47	MF	NA	68	68	NA	NA
Duncan et al. (1985)	21-37	M	NA	90	91	NA	NA
Kukkonen et al. (1982)	35-50	M	176	75	74	NA	NA
Martin et al. (1990)	43	M	NA	92	92	34	34
Nelson et al. (1986)	44	MF	NA	74	74	NA	NA
Seals & Reiling (1991)	61	MF	176	76	76	22	22
Urata et al. (1987)	32-60	MF	157	60	59	NA	NA

Note: NA = not available.

Blood Pressure Results for Diastolic Control Studies

Study	N	Pre (mmhg)	Post (mmHg)	SD (pre)	Dif. (pre-post)
Baglivo et al. (1990)	17	99	101	2	- 2
Bonanno & Lies (1974)	15	101	90	8	11
De Plaen & Detry (1980)	4	113	107	12	6
Duncan et al. (1985)	12	93	96	7	8
Kukkonen et al. (1982)	12	104	96	7	8
Martin et al. (1990)	14	94	94	4	0
Nelson et al. (1986)	13	99	96	4	3
Seals & Reiling (1991)	12	95	89	4	6
Urata et al. (1987)	10	97	99	6	- 2

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