SUMMARY

American College of Sports Medicine Position Stand: “PHYSICAL ACTIVITY, PHYSICAL FITNESS, AND HYPERTENSION.” Med. Sci. Sports Exerc., Vol. 25. No. 10, pp. i-x. 1993. Hypertension is present in epidemic proportions in adults of industrialized societies and is associated with a markedly increased risk of developing numerous cardiovascular pathologies. There is a continuing debate as to the efficacy of aggressive pharmacological therapy in individuals with mild to moderate elevations in blood pressure. This has led to a search for nonpharmacological therapies, such as exercise training, for these individuals. The available evidence indicates that endurance exercise training by individuals at high risk for developing hypertension will reduce the rise in blood pressure that occurs with time. Thus, it is the position of the American College of Sports Medicine that endurance exercise training is recommended as a nonpharmacological strategy to reduce the incidence of hypertension in susceptible individuals. A large number of studies indicate that endurance exercise training will elicit a 10 mm Hg average reduction in both systolic and diastolic blood pressures in individuals with mild essential hypertension (blood pressures 140-180/90-105 mm Hg). Endurance exercise training also has the capacity to improve other risk factors for cardiovascular disease in hypertensive individuals. Endurance exercise training appears to elicit even greater reductions in blood pressure in patients with secondary hypertension due to renal dysfunction. The mode (large muscle activities), frequency (3-5 d-wk-1), duration (20-60 min), and intensity (50-85% of maximal oxygen uptake) of the exercise recommended to achieve this effect are generally the same as those prescribed for developing and maintaining cardiovascular fitness in healthy adults. Exercise training at somewhat lower intensities (40-70% VO2max) appears to lower blood pressure as much, or more, than exercise at higher intensities, which may be important in specific hypertensive populations. Physically active and fit individuals with hypertension have markedly lower rates of mortality than sedentary, unfit hypertensive individuals. Thus, it seems reasonable to recommend exercise as the initial treatment strategy for individuals with mild to moderate essential hypertension. A follow-up period should assess the efficacy of the patient’s exercise program, and adjunct therapies should be implemented according to the individual patient’s blood pressure and CAD risk factor profile. Individuals with more marked elevations in blood pressure (>180/105 mm Hg) should add endurance exercise training to their treatment regimen only after initiating pharmacologic therapy. Resistive or strength, exercise training is not recommended to lower blood pressure in individuals with hypertension when done as their only form of exercise training. It is recommended when included as one component of a well-rounded fitness program, such as circuit training done in conjunction with endurance exercise training. Exercise testing is not advocated to determine normotensive individuals with an exaggerated exercise blood pressure response who might be at high risk of developing hypertension in the future. However, if exercise test results are available, they can be used to provide some indication of risk stratification and the need for appropriate lifestyle behavior counseling that might ameliorate this risk.

INTRODUCTION

Hypertension, defined as a blood pressure above 40/90 mm Hg, is present in 17% of adults according to the National Health and Nutrition Examination Survey (94). However, hypertension prevalence rates rise sharply with age and are also generally higher in men than in women and in blacks than in whites (59). At least 90% and probably as much as 95% of all hypertension is of unknown cause, i.e., primary or essential (59). Despite tremendous increases in the recognition and treatment of hypertension over the past 25 yr (9,25), the incidence of hypertension has not decreased (26). This Position Stand primarily addresses the effect of exercise training on individuals with hypertension and on those individuals at an increased risk of developing hypertension. In addition, this Position Stand also addresses the role of exercise testing in predicting those individuals at higher risk of developing hypertension in the future.

HYPERTENSION AND PREMATURE MORTALITY AND MORBIDITY

Men and women with blood pressures exceeding 160/95 mm Hg have a 50-300% higher annual incidence rate for coronary artery disease (CAD), congestive heart failure, intermittent claudication, and stroke than their normotensive peers (58). Women appear to tolerate increased blood pressures better than men as they have substantially lower incidence rates for these four cardiovascular pathologies than men with comparable blood pressures (58). On the other hand, black hypertensives have higher death rates than whites with the same blood pressure (59). Older individuals also have a substantially greater risk of a cardiovascular event than younger persons with the same elevation in blood pressure (59), indicating that an increase in blood pressure should not be accepted as an inconsequential concomitant of the aging process.

The dramatic benefits derived from aggressive pharmacological therapy for individuals with marked elevations in blood pressure were first demonstrated over 20 yr ago in the Veterans Administration Cooperative Study on individuals with diastolic blood pressures of 115-129 mm Hg (115), where 40% of patients receiving a placebo experienced a cardiovascular event compared with only 3% of patients receiving antihypertensive medications over the same time period. Numerous other trials have continued to demonstrate the dramatic benefits of pharmacological therapy in individuals with marked elevations in blood pressure (59).
Individuals with mild hypertension (140-160/90-105 mm Hg) are also at a greater risk of developing future cardiovascular morbidity (58). However, there is a continuing debate as to the efficacy of aggressive pharmacological therapy to reduce their cardiovascular risks, perhaps because of deleterious side effects of medications on other risk factors for CAD (59, 68). This debate has led to a search for nonpharmacological therapies, such as exercise training, for individuals with mild hypertension. Exercise training has also been proposed as a strategy to reduce the likelihood of a high-risk individual developing hypertension and to reduce mortality in individuals initiating an exercise program even if they remain hypertensive. In addition, exercise testing has been advocated as a means to identify normotensive individuals who may have a greater risk for developing hypertension in the future.

EXERCISE TESTING AND THE PREDICTION OF THE DEVELOPMENT OF HYPERTENSION

Over 50 yr ago the blood pressure responses of prehypertensive individuals to local cold (51) and mental tests (70) were found to be higher than those of individuals at lower risk for the future development of hypertension. Although most studies have shown that normotensive individuals with a family history of hypertension have more marked pressor responses to dynamic and isometric exercise than individuals without such a history (10, 76, 119), other studies have not reported such differences (cf., 106, 107). Several longitudinal studies indicate that normotensive individuals with a hypertensive response to exercise have an increased risk of developing hypertension in the future (20, 54, 69, 73, 103). These reports vary in the type of population studied, the mode of exercise testing, the definition of a hypertensive response to exercise, and the length of follow-up. Nevertheless, results are consistent with a two- to threefold increase in risk for developing hypertension in individuals with an exaggerated blood pressure response to exercise. The sensitivity and specificity of exercise hypertension to predict future hypertension at rest are modest (10), but these terms are usually discussed in reference to a diagnostic test where high values are required to have confidence in a definitive diagnosis. Screening tests to predict future disease or death have lower sensitivity and specificity than diagnostic tests, but screening is still useful to identify groups at risk. Thus, mass exercise testing is not recommended to identify future hypertensive individuals. However, if exercise test results are available, individuals with exercise blood pressure responses above the 85th or 90th percentile should be counselled about their increased risk for developing hypertension at rest in the future and given appropriate advice regarding health habits that might ameliorate that increased risk.

EXERCISE AND PREVENTION OF HYPERTENSION

Studies in animals. In animal models it is important to differentiate those animals that become hypertensive because of genetic influences [spontaneously hypertensive (SH) rats] from those that become hypertensive as a result of interventions such as hormonal injections (deoxycorticosterone), salt intake, or arterial constriction (two kidney-one clip). In the former, blood pressure is elevated because of interactions between genetic factors and the maturation process, whereas in the latter it is generally the magnitude and duration of the intervention that determines the rise in pressure. In general, the rise in blood pressure seen over time in SH rats is attenuated when they undergo exercise training during maturation, although the attenuation will not maintain their resting blood pressures within the normotensive range (108). This effect of training is seldom found in rat models of renal hypertension and is variable in salt-sensitive rats (106, 107). However, in these animal models the peripheral vasculature and renal structural changes that develop with hypertension are major and may totally eliminate the possibility of any physiological intervention maintaining a normotensive state.

Training intensity also appears to be an important consideration in SH rats because when the intensity exceeds 75% of their maximal oxygen consumption (VOzmax), higher than lower resting systolic blood pressures result (108, 113). On the other hand, when exercise intensity is 40-70% VOzmax, lower resting pressures are found for trained SH rats (108, 109).

Studies in humans. Six of 13 epidemiological studies reviewed in 1972 showed somewhat lower blood pressures in active compared with sedentary individuals (77). The remaining seven cross-sectional studies in this review by Montoye et al. (77) generally found no differences in blood pressure between active individuals and their less active peers. Reaven et al. (90) recently reported that in women a significant inverse relationship exists between physical activity and blood pressure, that the most active women had systolic and diastolic blood pressures 9-24 and 3-13 mm Hg lower, respectively, than the least active women, and that this relationship persisted after correcting for differences in body mass index. In the Tecumseh Community Health Study (77), the blood pressure of adult males was inversely related to occupational and leisure physical activity habits; however, the absolute difference in blood pressure was only 2-3 mm Hg between the most and least active men.

In more recent longitudinal studies, University of Pennsylvania alumni who played intramural sports less than 5 hr wk-1 were found to be 32% more likely to develop hypertension during 22-31 yr of follow-up than those who played sports more than 5 hr wk-1; similar results were evident when athletes and nonathletes were
compared (81). Follow-up surveys of this population indicated that participation in light or moderate activity later in life did not alter the incidence of hypertension, but alumni who had subsequently engaged in vigorous activity had a 19–29% lower rate of developing hypertension (83). Harvard alumni who did not participate in vigorous sports had a 35% higher incidence of hypertension during a 6-10 yr follow-up period (84). At the Institute for Aerobics Research in Dallas, physically unfit individuals, assessed by the results of treadmill exercise tests relative to age- and sex-specific norms, were 52% more likely than fit individuals to develop hypertension during a 4-yr follow-up period (13).

The first and only long-term primary prevention trial found that 75% of hypertension-prone men and women 30-44 yr of age in an exercise and dietary intervention increased their reported physical activity, and improved their exercise tolerance more than hypertension-prone controls (101). The incidence of new hypertension in this intervention group (8.8%) was 54% lower than the incidence in the control group (19.2%) over the 5-yr duration of the trial. However, since this trial combined several interventions it was not possible to assess the independent contribution of exercise toward lowering the incidence of hypertension.

Thus, recent large, long-term studies that allow for control of potentially confounding variables support the concept that regular exercise and increased aerobic fitness levels (V̇O_{2max}) reduce an individual’s risk of developing hypertension. However, most of these investigations studied white, middle-class males and little information is available for women, minorities, and other demographic groups.

**EFFECT OF EXERCISE ON INDIVIDUALS WITH HYPERTENSION**

**Studies in animals.** There have been very few studies in which hypertension was established before the animals began training. In SH rats older than 40 wk of age, moderate intensity exercise training for several months maintained resting blood pressure at their initial value, whereas SH rats not undergoing training exhibited a gradual increase in pressure over the same time (117). However, the available data on exercise training in animals do not convincingly support the concept that exercise training will lower blood pressures in those with established hypertension.

**Studies in humans.** Forty studies published prior to 1992 in the English literature have assessed the blood pressure-lowering effects of endurance exercise training on individuals with essential hypertension (2,5,7,8,14-16,18,19,22–24,27,29,32,36,38,44,47,49,50,55,56,62,64,66,67,74,78,79,92,93,95–97,102,114,116–118). All 1574 subjects enrolled in these studies initially had systolic hypertension (systolic blood pressure ≥ 140 mm Hg) while 755 subjects (48%) initially also had diastolic hypertension (diastolic blood pressure ≥ 90 mm Hg). Seventy-two percent of the groups in these studies that initially had systolic hypertension elicited significant decreases. in systolic blood pressure as a result of endurance exercise training. Their training-induced reduction in systolic blood pressure averaged approximately 11 mm Hg from an initial systolic pressure of 153 mm Hg. Seventy-seven percent of the groups that initially had diastolic hypertension in these studies reduced their diastolic pressure significantly with endurance exercise training. Their reduction in diastolic blood pressure with exercise training averaged approximately 9 mm Hg from an initial value of 99 mm Hg. Thus, these data indicate that endurance exercise training lowers casual systolic and diastolic blood pressure measured in the laboratory or in a clinic setting by approximately 10 mm Hg in the large majority of individuals with mild elevations in blood pressure.

Four studies in individuals with hypertension have assessed the impact of exercise training on the ambulatory blood pressures measured while they took part in their usual daily activities (14,36,98,100). Two of these studies found no changes in either casual or ambulatory pressures as a result of endurance exercise training (14,36). The two remaining studies (98,100) reported significant reductions in both casual and ambulatory blood pressures with exercise training in individuals with hypertension. However, the significant reduction in ambulatory blood pressure was generally only evident during the daytime hours, and the magnitude of the reduction was generally less than that observed in casual blood pressure. Thus, future studies must continue to assess the impact of exercise training on ambulatory blood pressure in individuals with hypertension, especially in light of the fact that ambulatory blood pressure is more indicative of their future prognosis (89).

Roughly half of the 40 investigations that have assessed the impact of endurance exercise training on individuals with hypertension studied only men and only two studies reported data from women separately. However, no studies that have compared men and women have found gender-related differences in the blood pressure changes elicited with exercise training (32,44,47,97,116). This would also appear to be the case in numerous other studies that included hypertensive men and women and made no specific mention of gender-related differences in blood pressure reductions elicited by endurance exercise training (2,7,8,14,18,23,24,27,36,38,64,66,78,79,114,117,118).

The subjects in these 40 studies ranged in age from 15-79 yr. The one study in adolescent hypertensives reported reductions in systolic blood pressure, and in diastolic blood pressure in those with diastolic hypertension (44), that approximated 10 mm Hg, even though their initial pressures were lower than those in older hypertensives. Studies that have assessed the
blood pressure-lowering effects of endurance exercise training programs longer than 3 months in hypertensive men and women over the age of 60 yr generally report reductions in blood pressure similar in magnitude to those elicited in younger hypertensives (18,24,32,47). The only races studied extensively have been Caucasians and Asians.

The few studies that are available generally indicate that the blood pressure-lowering effect of exercise training is also evident and quantitatively similar in patients taking antihypertensive medications (2,19,24,47,62); rat models of hypertension undergoing exercise training generally require less than normal amounts of antihypertensive medications (108). Thus, although the data support the general conclusion that endurance exercise training lowers blood pressure in individuals with essential hypertension, extrapolations of this conclusion to specific hypertensive populations and situations are, except for white middle-aged men and women, almost universally based on the results of single, or at best very few, studies.

A number of recent studies (24,47,55,64,66,93,97,114) have reported that training at 40-70% VO2max had the same, or greater, blood pressure-lowering effect as higher intensity training. Along these lines, it has also been shown that SH rats had lower blood pressures than nonexercising age-matched controls only if they trained at 40-70% VO2max (108,109). Thus, it appears that moderate-intensity training may elicit as great or greater reductions in blood pressure as higher intensity training; this may be especially important in specific populations of hypertensive individuals, such as the elderly, as acute cardiovascular and musculoskeletal risks will be reduced.

Most studies have found that blood pressure was reduced early (3 wk to 3 months) after the initiation of exercise training, and that up to 9 months of additional training failed to elicit further reductions in blood pressure (66,93,114). However, it was recently reported that older hypertensives who decreased their blood pressure significantly with 3 months of moderate-intensity training reduced both their systolic and diastolic blood pressures further with an additional 6 months of training (47). In a previous review (41), the reduction in diastolic blood pressure was found to be related to the length of the training, whereas the reduction in systolic pressure was not. Thus, although it appears that blood pressure may be reduced early after the initiation of an endurance exercise training program, it does not appear that prolonging such training beyond 3 months will result in further decreases in blood pressure, though this may not be the case with more moderate training intensities. However, those investigations that have had individuals with hypertension stop training indicate that their blood pressure returns to initial untrained levels (44,93,100). Thus, although more prolonged training may not bring about further reductions in blood pressure in individuals with hypertension, the blood pressure-lowering effect of exercise training is evident only as long as a regular endurance exercise training program is maintained.

It has been proposed that some specific subsets of hypertensive individuals might not lower their blood pressure in response to endurance exercise training. Recent studies and reviews have reported that overweight hypertensives (41), those with high initial plasma renin levels (66,114), low norepinephrine levels (29), high cardiac output (64), high serum sodium to potassium ratios (64), or those taking nonselective beta-blockade medications (2) show either no, or attenuated, blood pressure-lowering responses to endurance exercise training. However, this attenuated blood pressure-lowering response is not consistent in other studies that have investigated these specific subgroups of hypertensives (24,44,47,62). A recent study reported that hypertensive subjects with hypertensive exercise blood pressure responses did not change their systolic blood pressure and actually increased their diastolic blood pressure significantly (from 87-92 mm Hg) in response to exercise training (5). However, in the same study (3), hypertensives with normal blood pressure responses to exercise decreased their systolic and diastolic blood pressure significantly. This is the only study to report a significant increase in resting blood pressure in a group of hypertensive individuals as a result of exercise training. Finally, a recent review (41) indicated that in previous studies the magnitude of the reductions in systolic and diastolic blood pressure elicited with endurance exercise training were somewhat correlated to the initial diastolic blood pressure (≈ 0.34 and 0.46, respectively) but not to the initial systolic blood pressure.

Thus, there is minimal definitive evidence to support the conclusion that certain subsets of individuals with essential hypertension do not lower their blood pressure in response to endurance exercise training. However, in view of the recent report of strikingly different blood pressure responses to exercise training between hypertensives with normal vs exaggerated blood pressure responses to maximal exercise, further investigation is warranted.

Another important consideration for hypertensive individuals is the possibility that endurance exercise training may elicit other potential benefits in addition to lowering their blood pressure. The incidence of other modifiable CAD risk factors, including obesity, abnormal plasma lipoprotein-lipid profiles, insulin resistance, and glucose intolerance, is also more prevalent in hypertensive individuals (60,104). Endurance exercise training, in addition to reducing blood pressure in hypertensive individuals, also improves glucose intolerance and insulin resistance (52), obesity and caloric balance (17), and plasma lipoprotein-lipid profiles (121) in healthy individuals. Furthermore, some of these
beneficial training-induced adaptations have also already been demonstrated in individuals with essential hypertension \((15,38,62,97,102,116,1,18)\). These positive effects of exercise training are in contrast to the known deleterious side effects of many of the antihypertensive medications on CAD risk factors \((58)\). Preliminary research suggests that certain antihypertensive drug therapies such as beta-blockers may offset or negate the exercise training-induced increase in HDL-cholesterol levels \((30)\). However, the interactive effects of exercise and specific drug therapies on other CAD risk factors are largely unknown.

**Studies in humans with secondary hypertension.** Few studies have assessed the impact of exercise training on patients with secondary hypertension, probably because most of these patients have an underlying etiology that should be treated directly by standard medical, pharmacological, and surgical interventions. However, some patients with end-stage renal disease have endocrine abnormalities that maintain or exacerbate their hypertension even after their excess fluid volume is removed by dialysis. Two studies have reported that exercise training in end-stage renal disease patients decreases their systolic and diastolic blood pressures 2-3 times more than the reductions generally achieved in patients with essential hypertension, i.e., 20-30 mm Hg, and results in substantial reductions in the required dosages of their antihypertensive medications \((43,85)\). Another study also found that a small number of patients with hypertension secondary to renal dysfunction decreased their blood pressures with exercise training to a greater extent than those with essential hypertension \((19)\). Therefore, it appears that patients with secondary forms of hypertension related to renal dysfunction can also reduce their blood pressure with endurance exercise training, and to an even greater extent than individuals with essential hypertension.

**Death rates, fitness and hypertension.** A strong inverse gradient for age-adjusted all-cause mortality exists across physical activity strata in Harvard alumni \((82)\). Hypertensive University of Pennsylvania alumni who engaged in vigorous sports had a 37% lower age-adjusted all-cause death rate than sedentary hypertensive alumni \((83)\). Additional studies have shown that morbidity and mortality rates are also inversely related to physical fitness status in hypertensive individuals \((12,53,87)\). More recently in one study, fit hypertensive individuals were shown to have a 60% lower mortality rate than their unlit normotensive peers, and that the increased mortality associated with hypertension was completely overcome by fitness \((11)\). Although more research is clearly needed, especially in women, minorities, and other demographic groups, the existing studies support the conclusion that physical activity, and the resultant increased physical fitness, is an effective secondary intervention therapy in hypertensive individuals.

**Relative effectiveness of nonpharmacological therapies.** A review of weight loss studies \((59)\) found average reductions of 15 and 10 mm Hg in systolic and diastolic blood pressure, respectively, as a result of a 10-kg average weight loss. A recent review concluded that reducing dietary sodium intake by 80 meq \(\cdot d^{-1}\) was associated with a 5 and 3 mm Hg reduction in systolic and diastolic blood pressure, respectively, and that increasing dietary potassium intake by the same amount resulted in average reductions of 8 and 4 mm Hg for systolic and diastolic blood pressures, respectively \((59)\). Thus, overweight individuals who undergo a substantial weight loss elicit a reduction in blood pressure only slightly greater than that observed with endurance exercise training. However, altering sodium and potassium intake alone has a smaller effect on blood pressure than endurance exercise training \((59)\).

The other nonpharmacologic therapies proposed to induce an antihypertensive effect are behavioral modalities, such as relaxation and biofeedback. A review of 15 studies of the effect of biofeedback training, many of which lacked appropriate control groups, indicated that it reduces systolic and diastolic blood pressure by an average of 12 and 5 mm Hg, respectively, whereas relaxation techniques may be somewhat more effective with reductions averaging 18 and 11 mm Hg for systolic and diastolic blood pressure, respectively \((99)\). However, the addition of appropriate control groups in recent studies appears to have diminished the favorable effect of relaxation and biofeedback interventions to levels lower than those attained by endurance exercise training \((37,71)\).

**SAFETY OF ENDURANCE EXERCISE**

**Hemodynamic responses.** In unmedicated hypertensive individuals, acute exercise generally elicits a normal rise in systolic blood pressure from baseline levels, though the response may be exaggerated or diminished in certain patients \((88,120)\). However, because of their elevated baseline levels, the absolute levels of systolic blood pressure during exercise are usually higher in hypertensive persons. Furthermore, hypertensive persons may not change, or may even slightly increase, their diastolic blood pressure during incremental exercise probably as a result of an impaired vasodilatory response \((88)\). On the other hand, recent studies have demonstrated that individuals with essential hypertension can exhibit 10-20 mm Hg reductions in systolic blood pressure for 1-3 hr following 30-45 min of moderate-intensity exercise \((46,61)\). There is also some indication that this response may persist for up to 9 hr following acute exercise in individuals with hypertension \((86)\). This response appears to be...
diated by a transient decrease in stroke volume and, hence, cardiac output, perhaps due to a decrease in venous return, rather than a peripheral vasodilation that persists after the cessation of exercise (46, 80).

In view of the higher levels of blood pressure induced by exercise in individuals with hypertension, it has been postulated that they are at greater risk for sudden cardiac death or hemorrhagic stroke. However, at present there is no convincing evidence to substantiate this assumption in humans (35, 88), even though in young and mature stroke-prone SH rats moderate-intensity endurance exercise training increased the incidence of cerebrovascular lesions (110). Thus, it seems prudent to avoid an excessive rise in blood pressure during exercise training and, in patients with target organ involvement (e.g., left ventricular hypertrophy), to impose some restrictions on participation in vigorous exercise (35). The facts that high blood pressure is a major risk factor for CAD, which is by far the leading cause of sudden death during exercise, and the impaired coronary vasodilatory capacity in patients with left ventricular hypertrophy may provoke myocardial ischemia, even in the absence of severe CAD, should also be considered when prescribing exercise for hypertensive patients.

Interaction between exercise and medication.
Antihypertensive medications do not preclude participation in endurance exercise. Although most antihypertensive drugs do not substantially alter the blood pressure response to endurance exercise, they do lower resting blood pressure and, thus, the absolute level attained (21, 88). Beta-blockers, however, can attenuate the magnitude of the rise in systolic blood pressure during endurance exercise as well as resting blood pressure. Consequently, they may be considered as the antihypertensive agents of greatest potential benefit to hypertensive persons who have an excessive rise in systolic blood pressure during dynamic exercise. Unfortunately, the usefulness of beta-blockers, especially nonselective ones, is often considerably limited by a concomitant impairment of exercise tolerance in persons without myocardial ischemia (40) and the possibility that they may blunt the exercise-training-induced lowering of blood pressure (2) and the exercise-induced increases in HDL-cholesterol (30) in hypertensive individuals. Therefore, unless beta-blocker therapy is specifically indicated, other agents with more favorable side effect profiles should be considered for such patients. In this regard, angiotensin-converting enzyme inhibitors, calcium channel blockers, and alpha-blockers are especially well suited for persons with uncomplicated essential hypertension and physically active lifestyles (3, 40). Irrespective of the drugs prescribed, the physician and patient should be aware of their interaction with exercise and whether any special precautions are needed (35).

Safety and effects of resistive exercise training.
Patients with high blood pressure have traditionally been discouraged from participating in resistive training for fear of precipitating a cerebrovascular event or imposing an excessive demand on an already-compromised myocardium. Such fears have arisen largely as a result of the marked pressor response elicited during acute high-intensity resistive exercise (34, 72). However, studies investigating the impact of chronic resistive training on resting blood pressure have, in fact, not documented such an adverse effect. On the contrary, although considerable additional research is needed, the results of some (42, 50, 62, 65), but not all (6, 14, 24), studies suggest that resistive training, especially circuit weight training, may lower resting blood pressure.

Experimental evidence on the effects of acute and chronic resistive training on the risk for cerebrovascular complications in humans with high blood pressure is not available. Recently stroke-prone hypertensive rats were found to not increase their development of cerebrovascular lesions with long-term resistive exercise training (111). Although considerable further research is required before these findings can be extrapolated to humans with high blood pressure, they do indicate that resistive training may not necessarily increase the risk for cerebrovascular lesions.

Resistive training produces concentric left ventricular hypertrophy in some individuals. In hypertensive patients, concentric left ventricular hypertrophy is associated with an accentuated risk of cardiovascular events even in the absence of other CAD risk factors (28). In general, the magnitude of cardiac hypertrophy is smaller than the hypertrophy produced by chronic hypertension, perhaps in part due to the mild to moderate and intermittent nature of the pressure overload associated with resistive training compared with the chronic elevated pressure state associated with hypertension. In fact, resistive training is typically characterized by normal diastolic function, in contrast to what occurs with pathologic concentric hypertrophy. Thus, although the eccentric hypertrophy elicited by endurance training is seemingly more desirable, resistive training does not appear to produce any adverse effects on left ventricular function (31, 39).

**POTENTIAL MECHANISMS UNDERLYING THE ANTIHYPTERTENSIVE EFFECT OF EXERCISE TRAINING**

At present the mechanisms by which exercise training decreases blood pressure in hypertensive individuals are unclear. This effect is probably not mediated by a single mechanism, and for the different types of hypertension or in heterogeneous hypertensive populations, different mechanisms are possible. The blood pressure-lowering effect of exercise is, however, independent of decreases
in body weight and body fat (2,5,7,15,16,22,24,29, 44,55,64,74,78,97,102,114).

In most individuals with long-standing hypertension, total peripheral resistance (TPR) is usually increased at rest (1). However, in the limited number of studies in humans that have measured cardiovascular hemodynamics, reductions in both cardiac output and TPR have been observed after training (41,107). Recently, trained SH rats were shown to have a lower cardiac output and blood pressure at rest than their sedentary strain-matched counterparts, although their TPR was actually increased (109).

The sympathetic nervous system (SNS) is believed to play a central role in essential hypertension (1,75), and there is evidence that the decrease in pressure with exercise training in some hypertensives is associated with a decrease in plasma norepinephrine levels (29,47,66,114). This effect may be especially important in hypertensives who have high plasma norepinephrine levels at rest, where the reduction in blood pressure elicited with endurance exercise training was significantly correlated to the changes in plasma norepinephrine levels (29). In addition, chemically sympathectomized SH rats have been shown to undergo less of a rise in blood pressure with exercise training than their treatment-matched sedentary counterparts (112). The fact that not all studies have found a decrease in plasma norepinephrine with training (23,24,45) does not rule out SNS involvement as plasma norepinephrine levels are only an indirect estimate of SNS activity and small, but potentially important, training-induced decreases in peripheral SNS activity may not be detectable by measuring plasma norepinephrine levels (33).

Conversely the lowering of blood pressure with exercise training could be due to an increase in circulating vasodilator substances. However, except for a suggested role for endorphins (105), there are no consistent data indicating that the blood pressure-lowering effect of exercise training is mediated by compounds such as prostaglandins, kinins, adenosine, dopamine, or atrial natriuretic factor.

Recently, hyperinsulinemia secondary to insulin resistance has been proposed as a potential mechanism responsible for the development of hypertension and the increased incidence of diabetes, upper body obesity, hypertriglyceridemia, and CAD that occur in hypertensive individuals (91). However, although it is known that exercise training can ameliorate an individual’s hyperinsulinemic state (52), no studies have yet assessed if this mechanism is involved in the blood pressure-lowering effect of endurance exercise training.

The kidney, because of its ability to regulate body sodium, and thus plasma volume and cardiac output, is believed to play a dominant role in maintaining the increased blood pressure in essential hypertension (48). Thus, exercise training may lower blood pressure by altering renal function (63). Although acute exercise influences various hormones that may influence renal sodium metabolism (e.g., renin, angiotensin, aldosterone, atrial natriuretic factor, prostaglandins, and insulin, (122)) there are no consistent data implicating these compounds in the blood pressure-lowering effect of endurance exercise training.

CONCLUSIONS

The American College of Sports Medicine makes the following recommendations regarding exercise testing and exercise training of persons with hypertension:

1. Mass exercise testing is not advocated to determine those individuals at high risk for developing hypertension at rest in the future as a result of an exaggerated exercise blood pressure response. However, if exercise test results are available and an individual has an exercise blood pressure response above the 85th percentile, this information does provide some indication of risk stratification for that patient and the necessity for appropriate lifestyle behavior counseling to ameliorate this increased risk.

2. Endurance exercise training by individuals who are at high risk for developing hypertension will reduce the rise in blood pressure that occurs with time, thus justifying its use as a nonpharmacological strategy to reduce the incidence of hypertension in susceptible individuals.

3. Endurance exercise training will elicit an average reduction of 10 mm Hg for both systolic and diastolic blood pressures in individuals with mild essential hypertension (blood pressures in the range of 140-180/90-105 mm Hg). Endurance exercise training appears to elicit even greater reductions in blood pressure in patients with secondary hypertension due to renal dysfunction. The mode (large muscle activities), frequency (3-5 d wk⁻¹), duration (20-60 min), and intensity of exercise (50-85% of maximal oxygen uptake) recommended are generally the same as those outlined in the previous Position Stand of the American College of Sports Medicine entitled “The Recommended Quality and Quantity of Exercise for Developing and Maintaining Cardiorespiratory and Muscular Fitness in Healthy Adults” (4). Exercise training at somewhat lower intensities (40-70% V̇O₂max) appears to lower blood pressure as much, or more, than exercise at higher intensities, which may be especially important in specific hypertensive populations, such as the elderly. Physically active and aerobically fit patients with hypertension have markedly lower rates of mortality than sedentary, unfit hypertensive individuals, probably because exercise training also improves a number of other cardiovascular disease risk factors. In concurrence with the Joint National Committee’s Recommendations for the Treatment of Essential Hypertension (57) and based on the high number of exercise-related health benefits and low
risk for morbidity/mortality, it seems reasonable to recommend exercise as part of the initial treatment strategy for individuals with mild to moderate essential hypertension. A follow-up period should assess the efficacy of the patient’s exercise program, and adjunct therapies should be implemented according to the individual patient’s blood pressure and CAD risk factor goals.

4. Individuals with more marked elevations in blood pressure (>180/105) should add endurance exercise training to their treatment regimen only after initiating pharmacologic therapy, as it may reduce their blood pressure further, allow them to decrease their antihypertensive medications, and attenuate their risk for premature mortality.

5. Resistive, or strength, training is not recommended as the only form of exercise training for hypertensive individuals as, with the exception of circuit weight training, it has not consistently been shown to lower blood pressure. Thus, resistive exercise training is recommended when done as one component of a well-rounded fitness program, but not when done independently.

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