Regular Exercise as an Effective Approach in Antihypertensive Therapy

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ABSTRACT

KETELHUT, R. G., I. W. FRANZ, and J. SCHOLZE. Regular Exercise as an Effective Approach in Antihypertensive Therapy. *Med. Sci. Sports Exerc.*, Vol. 36, No. 1, pp. 4–8, 2004. **Purpose:** Exercise has been well documented to exert a beneficial effect on cardiovascular health. The effective control of arterial pressure (BP) is essential from the standpoint of cardiovascular prevention. So far, no study has determined the long-term effect of regular training as a monotherapy on both BP at rest and during exercise. **Methods:** Therefore, 10 subjects with hypertension (aged 43 ± 3 yr) were studied in order to define BP response to long-term aerobic training. BP measurements were obtained at rest and during ergometry (50–100 W). Patients were instructed to exercise weekly (2 × 60 min aerobic exercise). **Results:** BP during exercise (100 W) did fall already after 6 months of regular training from 184 ± 10/107 ± 6 to 170 ± 10/100 ± 7, and this was associated with a 14% decrease in the rate-pressure product (at 100 W). After 18 months of training, there were further reductions in BP, at rest from 139 ± 9/96 ± 6 to 133 ± 14/91 ± 7 ($P < 0.05$) and during ergometry (100 W) from 184 ± 10/107 ± 6 to 172 ± 8/96 ± 6 mm Hg ($P < 0.001$). During a 3-yr follow-up, BP continued to decrease significantly to 130 ± 13/87 ± 7 mm Hg at rest and 167 ± 9/92 ± 6 mm Hg during exercise. No significant changes in body weight were documented during the training period. **Conclusion:** The data demonstrate that long-term aerobic exercise is associated with a decrease in BP at rest and during exercise, which is comparable to that of drug therapies. This antihypertensive effect of regular training can be maintained as long as 3 yr. **Key Words:** HYPERTENSION, AEROBIC EXERCISE, BLOOD PRESSURE, INTERVENTION, ANTIHYPERTENSIVE TREATMENT, EXERCISE TESTING

Arterial hypertension is a major predictor of premature cardiovascular morbidity and mortality (22), which can be successfully treated with antihypertensive medication. Morbidity and mortality increases as arterial pressure rises, with no evidence of a threshold of risk (23). Regular exercise, particularly aerobic exercise, has been well documented to modulate cardiovascular risk profile (13) and to reduce cardiovascular morbidity and mortality in physically active subjects (12,24). The effective control of major risk factors such as high blood pressure (BP) is essential from the standpoint of preventive medicine and public health. It must be asked, however, whether the drug therapy of hypertension will continue to play the dominant role in hypertensive management given the large financial burden that is imposed by the use of antihypertensive drugs on a broad scale.

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The guidelines of the World Health Organization and International Society of Hypertension and the National Committee of High Blood Pressure recommend exercise training for primary management of hypertension besides medical therapy (29). Whether regular exercise is effective in preventing hypertension is still unknown, but several indirect lines of evidence support the concept that increased physical activity may have a protective effect on BP regulation.

But there are still conflicting results concerning the long-term effect of aerobic exercise and, moreover, its position as a monotherapy on BP in hypertensive therapy. Some studies did not mention lifestyle changes or weight loss besides exercise intervention. However, this information is essential if the role of exercise alone, as compared with other changes, is to be assessed. Most data suggest that at least an extent of training of three or more times a week is needed to obtain a pressure-lowering effect. Furthermore, most studies are limited to BP changes occurring only at rest and short intervention periods (5,28). Because an increasing number of hypertensives are physically active and take part in sports, it seems a logical goal of antihypertensive treatment to reduce arterial pressure both at rest and during exercise. Furthermore, this is especially important because some persons may show a marked lability in BP at rest and may appear to be at greater risk than is real. Measuring pressure

during exercise may reduce this lability and reduce the risk of a false diagnosis. On the other hand, measurement of arterial pressure during exercise may be even a better risk indicator as exemplified in long-term studies where exercise-induced pressure increase proved to be a risk factor independent of resting pressure for myocardial infarction and for total and noncardiovascular mortality (9,20).

Previously (16) it has been demonstrated that, during a single bout of aerobic exercise, there is a continuous decrease in systolic and diastolic pressure in hypertensive humans during aerobic exercise under steady-state conditions. A following transient postexercise hypotension has been shown to persist for as long as almost 2 h (16). The implication of this acute mechanism in the long-term influence of arterial pressure due to regular exercise has been discussed frequently. Therefore, a 3-yr interventional program was initiated to determine the influence of a regular long-term aerobic training twice weekly on BP at rest and during exercise testing. A further objective was to assess the position of endurance training as a nonpharmacological therapeutic tool in the management of arterial hypertension when compared with medical therapy.

METHODS

Ten male hypertensive patients (aged 43.3 ± 3.1 yr) were recruited from the community via media advertisement. All volunteers were newly diagnosed with hypertension with either mild hypertension at rest (systolic BP of 130–159 mm Hg and/or diastolic BP of 85–99 mm Hg) and elevated pressure during standardized ergometric testing (systolic BP above 200 mm Hg and/or diastolic BP above 100 mm Hg at 100 W) determined on two separate days. None received any medication, and all participated in the study after giving informed consent. Patients, all nonsmokers, had previously sedentary lifestyles, as defined by the absence of a regular exercise program during the preceding 10 yr. Before the beginning of regular exercise, all patients underwent a full medical examination on a work-free Saturday. None had coronary heart disease or heart failure, and their serum creatinine concentration did not exceed 1.1 mg·dL^{-1}. Careful physical and laboratory examinations were performed to rule out secondary hypertension and serious cardiovascular or cerebrovascular complications. Arterial pressure was measured indirectly with a conventional mercury sphygmomanometer according to the Riva-Rocci-Korotkoff cuff method in a supine position. Then the patients were subjected to a standardized ergometric testing in a half-sitting position on a stationary bicycle ergometer under controlled conditions, using techniques given in the Proposal for International Standardization of Ergometry (1). The exercise load started at 50 W, with an increase of 10 W every minute to a maximum of 100 W. During the bicycle ergometry, arterial pressure readings were taken every minute at the end of each exercise stage and 5 min at rest after the exercise test. Heart rate was monitored by ECG continuously during the test. The product of rate times systolic pressure was calculated at 100 W. All measurements were performed by the same physician. This procedure was conducted pretraining and then repeated under identical conditions 6 months, 1.5, and 3 yr after regular training.

The exercise program consisted of two outdoor training sessions per week. Group training sessions were supervised by a qualified instructor. Each session started with a 5-min warm-up and was finished with a 5 min cooling down. In the first 4 wk, the exercise program consisted of walking and intermittent slow jogging. In the following 5 months, subjects progressed from 5 to 30 min of slow running with a further continuous increase to a maximum of about 60 min long distance running 2× wk^{-1}. Heart rate was controlled during all training sessions to maintain the target heart rate of 60–70% of age-related maximal heart rate. All sessions were strictly supervised by a physician who also kept records of attendance. Patients were advised not to alter their dietary habits during the study and not to participate in exercise programs outside of the scheduled classes. Statistical analysis was performed using the Student's *t*-test for paired observations, and data were expressed as mean ± standard deviation. The level of significance was considered to be $P < 0.05$.

All participants signed an informed consent that was consistent with the MSSE guidelines and had been approved by the Institutional Review Board.

RESULTS

Because there was no control group in this study, patients were used as their own control with an initial 3.3 ± 1.2 months recruitment period before the onset of training taken as the control period. After this period, there was a significant decrease in systolic pressure at rest from p1 (1: pretraining examination) to p2 (2: pretraining examination) ($P < 0.01$). During ergometric testing at 100 W, pressure did not change significantly (Table 1).

After 6 months of training, baseline resting BP did not change significantly, whereas both systolic and diastolic BP at 100 W were already significantly lower when compared with pretraining (Table 1). Because heart rate was lower during exercise, this was accompanied by a 14% decrease in the rate pressure product during an exercise load of 100 W (Fig. 1). After 1.5 yr of training, there was a significant reduction in resting BP from pretraining to 1.5 yr after aerobic training (Table 1). During the standardized ergometric testing at a workload of 100 W, both systolic and diastolic pressure decreased significantly (Fig. 1, Table 1). Simultaneously the heart rate dropped significantly ($P < 0.01$) from 116 ± 11 min^{-1} preexercise to 106 ± 9 min^{-1} after 1.5 yr of exercise, and the rate-pressure product, reflecting the level of myocardial oxygen consumption, decreased significantly from 21.344 before training to 18.020 after 1.5 yr of training ($P < 0.01$, 15.6%) (Fig. 2). A significant decrease in BP in the 5th minute of the recovery period could be observed as well, when compared with preexercise and 1.5 yr of intervention (Table 1).

All subjects but one were still in the study after 3 yr of regular exercise. During follow-up, there were further de-

TABLE 1. Systolic and diastolic pressure in hypertensive patients at rest, during ergometric testing (100 W) and in the 5th minute of the recovery phase before and after long-term aerobic training.

Training (yr)	p1	p2	0.5	1.5	3
Rest					
SBP	151 ± 11	139 ± 9	138 ± 14	133 ± 14*	130 ± 13*
DBP	96 ± 7	96 ± 6	94 ± 9	91 ± 7*	87 ± 7*
Exercise (100 W)					
SBP	188 ± 9	184 ± 10	170 ± 10*	172 ± 8*	167 ± 9**
DBP	106 ± 6	107 ± 6	100 ± 7**	96 ± 6**	92 ± 6***
After exercise (5 min)					
SBP	144 ± 7	143 ± 12	134 ± 10	135 ± 10	131 ± 15
DBP	96 ± 6	100 ± 8	92 ± 8*	88 ± 7**	86 ± 7**

Data are the mean ± 1 SD.
* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$ (all vs p2).
SBP, systolic blood pressure; DBP, diastolic blood pressure.

creases in systolic and diastolic pressures at rest and during exercise. Systolic BP decreased to a total of 16 mm Hg (8.7%) and diastolic to 15 mm Hg (14%) after 3 yr of regular training. This was also true for BP at rest after exercise (Table 1, Fig. 1) and the rate-pressure product at 100 W (Fig. 2). Furthermore, there was a significant reduction ($P < 0.01$) in the magnitude of exercise-induced diastolic pressure increase (at 100 W) versus resting conditions when compared pretraining (5.7%) with 3 yr of exercise (11.5%), demonstrating an improved exercise induced vasodilatation. No significant changes in body weight were documented during the training period (average increase 0.2 kg). The average training participation rate of the whole group was 86% (134 session) throughout the 3-yr intervention period.

DISCUSSION

As stated earlier, aerobic exercise has been proven to lower not only overall mortality but more significantly cardiovascular mortality and morbidity. The main mechanism is due to its positive influence on various cardiovascular risk factors. The major purpose of the present study was to determine the effects of a long-term endurance training program on arterial pressure in hypertensive subjects. The results demonstrated that not only pressures at rest were lower after long-term aerobic exercise but, moreover, pressures during ergometric exercise were substantially lower when compared with pretraining measurements. This is more important since recent findings (21,26) identified BP levels as monitored during exercise to correlate more closely with end-organ damage, such as left ventricular hypertrophy, than casual or resting BP measured in a clinic or physician's office. Furthermore, a prospective study of Filipovský et al. (9) demonstrated that the magnitude of exercise-induced increase in systolic pressure represents a risk factor for death from cardiovascular as well as noncardiovascular causes independently of resting pressures. A similar outcome was demonstrated by Mundal et al. (20) in which exercise-induced pressure increase proved to be a risk factor independent of resting pressure for myocardial infarction and for total and noncardiovascular mortality.

The arterial pressure-lowering effect of endurance training in the present study was more intensive than what we found using various antihypertensive medications. In this regard, it could be demonstrated that the decrease in systolic pressure of 9.2% during ergometric workload (100 W) after 3 yr is more intensive than what we found in hypertensive controls using prazosin (3.2%, $N = 24$), diuretics (4.3%, $N = 54$), gallopamil (4.4%, $N = 40$), or enalapril (6.2%, $N = 26$) and is in the range of moderate nifedipine doses (20 mg: 7%, $N = 35$; 40 mg: 9.2%, $N = 45$) but substantially lower than beta-blocking agents (16.6%, $N = 473$) (14). In con-

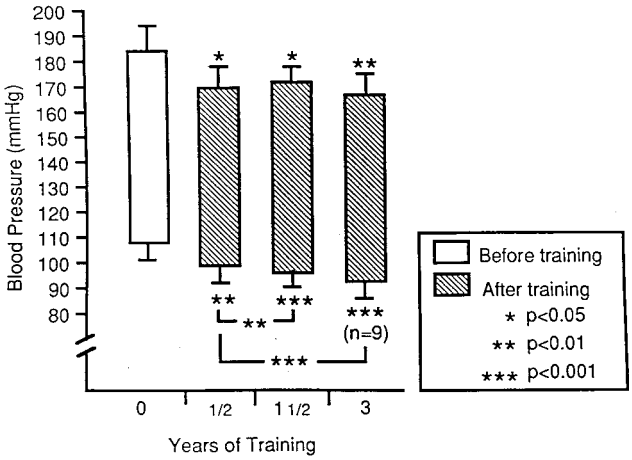

FIGURE 1—Systolic and diastolic pressure in hypertensive patients during ergometric testing (100 W) before and after long-term aerobic training (mean ± 1 SD).

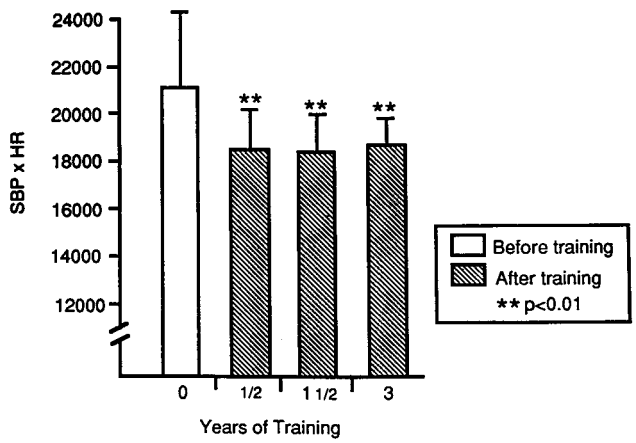

FIGURE 2—Systolic pressure (SBP) × heart rate (HR) during standardized ergometric exercise (100 W) before and after regular aerobic training in hypertensive subjects (mean ± 1 SD).

trast, Blumenthal et al. (3) assessed the effects of a moderate aerobic exercise program in patients classified as mild hypertensives, based on resting BP and ambulatory BP monitoring. After 4 months of exercise ($3\times$ wk^{-1}, at 70% $\dot{V}O_{2max}$), subjects in the exercise group did not exhibit greater BP reductions than the controls. So were the results of other studies (10), which observed only mild reductions in pressures at rest. Even in the present study, subjects exhibited a mild and not significant decrease in BP only at rest after 6 months of regular training, but BP continued to decrease in the long-term observation period. Therefore, from our results, it can be concluded that, besides intensity, the duration of exercise intervention may be the more important underlying influential parameter of the BP-lowering effect due to regular exercise.

The mechanisms underlying the pressure-lowering effect of aerobic exercise have not been fully clarified. Physical training causes peripheral vasodilation and increases tissue perfusion (18). Because the magnitude of exercise-induced pressure (at 100 W) versus resting conditions is lower especially in diastolic pressure, a reduced vascular peripheral resistance may contribute to the decline in BP as one of the main mechanisms (8,19). A change in cardiac output cannot be ruled out (11) and has been demonstrated to be responsible for a depressor effect after an acute exercise bout (15). Individuals with essential hypertension are also known to have reduced insulin sensitivity compared with normotensives (7). Physical fitness is a major determinant of insulin sensitivity (27), and regular exercise induces weight loss. Because over the last decade increasing attention has highlighted the association between insulin concentrations and various metabolic disorders, including hypertension, a decrease in insulin concentration has to be discussed as a mechanism for lowering arterial pressure by aerobic exercise as well (30).

Endothelial adaptation and endothelium-derived modulators may also display profound changes with regular aerobic training (4). A likely sequence of events to explain the effects of regular exercise includes a primary vascular change in small vessels involving endothelium-mediated vasodilatation, which has been shown to improve after regular cycling (17). Much research has focused on a probable decline in sympathetic autonomic control and a reduction in circulating catecholamines due to conditioning. A recent published animal study suggests that increased venule density is a specific adaptation of skeletal muscle to training. By increasing the venular bed in the exercising muscles and favoring a reduction in blood volume/vascular capacity ratio, it might contribute to the exercise induced pressure-lowering effect (2).

The observations in the present study were based on a small sample size, and there was no control group, which can be seen as a drawback. But the patients were used as their own control with the initial 3–4 months before the onset of training taken as the control period. After this control period, BP during ergometric testing and in the 5th minute after was reproducible with no statistically significant differences, whereas arterial pressure at rest decreased significantly in the respective period. Besides the pressure-lowering effect of regular exercise, one has to ask about the prognostic outcome of such a long-term therapy due to the incidence of cardiovascular diseases and death. In this regard, recently published data of a prospective cohort study (6) support the view that not only men who exercise regularly have lower rate of cardiovascular morbidity and mortality but moreover that this protective effect is enhanced in hypertensive subjects.

The data reported here support the concept that cardiovascular diseases due to hypertension may be prevented by increasing physical activity and that vigorous activities, such as long-distance running, may have an even stronger protective or pressure lowering effect than less vigorous activities, although this has not been a consistent observation (5). Even more, there was a decrease in heart rate in the present study. Because we learned that elevated heart rate, *per se*, is a risk factor not only for hypertension itself but for cardiac disease and mortality (25) and other end points, this has to be mentioned as an additional positive side effect of regular training besides its pressure-lowering effect. It is unlikely that the BP reduction in this study was attributable to a weight reduction, because there was no significant change in body weight during the training period. A reduction in sodium intake has to be discussed as well, as it is known that a moderate reduction in sodium intake can be effective in lowering arterial pressure in some normotensive and hypertensive subjects irrespective of the baseline pressure. But before intervention, the studied patients were advised not to alter their dietary habits during the study; therefore, it is unlikely that their habitual sodium intake was reduced.

The reduction in BP in hypertensive patients seen after long-term aerobic training therefore implies that exercise has a beneficial effect in the management of hypertension and that pharmacological treatment can be deferred or probably prevented in hypertensive subjects who regularly engage in aerobic sports activities. We suggest that exercise should be recommended as an adjunct to proper diet and weight control for the prevention of cardiovascular diseases due to arterial hypertension. Furthermore, these results demonstrate that in men with physician-diagnosed hypertension, exercise is associated with a decrease in arterial pressure at rest as well as during exercise and that this antihypertensive effect of regular training can be improved and maintained for as long as 3 yr.

It can be concluded that in hypertensive patients a moderate regular aerobic exercise program results in a continuous and long-term decrease in both systolic and diastolic pressure at rest and during exercise. Regular exercise implies a beneficial effect in the management of hypertension that is comparable to that of drug therapy. An additional advantage of physical activity is other healthy "side effects" that are known to influence cardiovascular risk. The disadvantage of taking drugs daily with its risk of side effects and costs may be avoided, and patients feel that they can affect their well-being and are not victims of disease. Therefore, regular aerobic exercise should be recommended in the management of arterial hypertension. From a public health

perspective, these results may have important implications for regular physical activity promotion in our society.

This paper is dedicated to Prof. Dr. Ingomar-W. Franz for his 60th birthday.

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