Effects of exercise and weight loss on blood pressure during daily life

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ABSTRACT

STEFFEN, P. R., A. SHERWOOD, E. C. D. GULLETTE, A. GEORGIADES, A. HINDERLITER, and J. A. BLUMENTHAL. Effects of exercise and weight loss on blood pressure during daily life. *Med. Sci. Sports Exerc.*, Vol. 33, No. 10, 2001, pp. 1635–1640. **Purpose:** The objective of this study was to investigate the effects of exercise training and weight loss on blood pressure (BP) associated with physical activity and emotional stress during daily life. **Methods:** One hundred twelve participants with unmedicated high normal or stage 1 to stage 2 hypertension were randomized to one of three conditions: a combined exercise and behavioral weight management group (WM), an exercise-only group (EX), or a wait list control group (CON). BP was assessed in the clinic and during 15 h of daytime ambulatory BP monitoring at baseline and after 6 months of treatment. **Results:** Increased levels of physical activity and emotional distress measured during daily life were associated with increases in systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate (HR), and rate pressure product (RPP). After treatment, the WM group had significantly lower DBP, HR, and RPP responses during both high and low levels of physical activity and emotional distress compared with the CON group. The EX group had similar BP levels as the WM group, although the EX group had significantly lower BP than the CON group during low but not high levels of physical activity and emotional distress. **Conclusion:** These findings indicate that exercise, especially when combined with weight loss, reduces BP levels at rest and in situations that typically elevate BP such as intense physical activity and emotional distress. **Key Words:** STRESS, AMBULATORY MONITORING, PHYSICAL ACTIVITY, EMOTIONAL DISTRESS, AMBULATORY BLOOD PRESSURE

Although observational and interventional studies generally have demonstrated that exercise training reduces blood pressure (BP) in hypertensive individuals (2,16,18,30), the majority of studies examining the effects of exercise on BP have limited BP measurements to clinic settings (2,16,18). Recently, studies have demonstrated that BP measured during mental stress testing and during daily life using ambulatory BP (ABP) monitoring may have greater clinical significance than BP measured in the clinic. For example, elevated BP in response to behavioral and psychosocial stressors is related to a higher incidence of hypertension and cardiovascular disease (7,12,26,33), and elevated BP during daily life assessed using ABP monitoring has been shown to be a stronger predictor of left ventricular hypertrophy (11,20) and myocardial infarction and stroke (32,35) than standard clinic measurement.

Several studies have shown that exercise training reduces BP during mental stress testing (3,4,10,24,29). Cross-sectional studies have shown that individuals who exercise regularly have lower BP levels during psychosocial stressors and recover more quickly after the stressor as compared with controls (10,24). Longitudinal studies of exercise generally have found that exercise training leads to reduced BP responses to psychosocial stressors (3,4,29). However, changes in body weight or dietary habits were not assessed. Moreover, results from studies examining the effects of exercise on ABP have been mixed (1,6,9,13,21,23,27,31,34). Some studies have shown that exercise reduces daytime ABP only (9,21,23,27,31,34), whereas others have found no effect (1,6,13). Interestingly, a recent study found that exercise combined with weight loss led to a larger reduction in ABP as compared with exercise alone (9).

Studies also have shown that physical activity and emotional distress during daily life contribute to ABP changes (14,25,28). Daily physical activities, such as clerical work, housework, and walking elevate ABP, with activities requiring more physical effort resulting in higher BP levels. Emotional distress has also been shown to be related to increased ABP in ambulatory studies (25,28). To our knowledge, however, the extent to which exercise training and weight loss may affect ABP responses during specific activities of daily life has not been studied. The current study examined the effects of an exercise and weight loss intervention on

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ABP responses to physical activity and emotional distress during a typical day.

METHODS

Overview

This study was approved by the Institutional Review Board at Duke University Medical Center and written informed consent was obtained from all study participants. Initial screening included a medical history and physical examination and blood pressure determination to determine eligibility. Baseline (pretreatment) assessments included 12- to 15-h ambulatory blood pressure monitoring during waking hours on a typical workday. After the completion of the pretreatment assessments, participants were randomly assigned to one of three treatment groups: exercise only (EX), exercise plus a behavioral weight loss program (WM), or waiting list control (CON). All measurements, including both clinic and ambulatory BP measurements, which were obtained at baseline, were repeated after 6 months of treatment. A detailed description of the study design and main results are presented elsewhere (5).

Subjects

Participants were recruited from newspaper, television, and radio advertisements; referrals from local clinics; and BP screenings at community health fairs and shopping centers. Subjects were eligible if they were at least 29 yr old, were sedentary, were overweight or obese (body mass index (BMI) of 25–37 $kg \cdot m^{-2}$), and had systolic blood pressure (SBP) between 130 and 180 mm Hg and diastolic blood pressure (DBP) between 85 and 105 mm Hg. In this manner, 133 men ($N = 59$) and women ($N = 74$), 23% of whom were African-American, were enrolled in the study.

Blood Pressure Measurement

Clinic blood pressure. To determine subject eligibility, BP was measured by a trained staff member on four separate visits over a 3-wk period. At each visit, BP was measured with a random zero sphygmomanometer with standardized cuff size and position four times at 2-min intervals after an initial rest period of 5 min. The first BP measurement of each visit was discarded and the average of the remaining three measurements represented the clinic visit BP. The overall clinic BP was then determined by averaging the mean BPs over the four visits. This procedure was performed at baseline and at the 6-month follow-up.

Ambulatory blood pressure assessment. A typical workday was chosen for the ABP studies. Subjects were instrumented between 0800 and 1000 h with an Accutracker II unit (Suntech, Raleigh, NC), and SBP and DBP recordings were verified by simultaneous manual readings. The Accutracker II measures BP noninvasively using the auscultatory technique, in which a microphone records and processes Korotkoff sounds; it uses ECG R-wave gating to correctly identify Korotkoff sounds originating from the brachial artery (36). The monitor was programmed to obtain readings at an average frequency of four $times \cdot h^{-1}$ until bedtime. All ABP readings were reviewed by an experienced staff member, and readings judged invalid (i.e., because of artifact) were excluded. The mean ambulatory SBP and DBP were then computed on the basis of all remaining readings.

Diary assessment. Subjects were instructed to complete a brief one-page set of diary items indicating time, posture, location, activity, alcohol and caffeine consumption, and mood levels at the time of each ABP cuff inflation. This type of diary has been used previously (15). Physical activities included the following: going to sleep, sleeping, rest, washing/dressing, urinating/defecating, driving/passenger, shopping, eating/drinking, house activity, walking, stair climbing/descending, sexual activity, talking/listening, reading, clerical work, TV/radio, thinking, waiting, or other. Subjects circled the activities in which they were engaged each time the BP cuff inflated. Subjects also rated their mood (tense, frustrated, sad, stressed, in control, and happy) on a five-point Likert scale, ranging from 1 (“not at all”) to 5 (“very much”).

Interventions

EX group. Participants in the aerobic exercise only group participated in a supervised exercise program in which they exercised 3–4 $times \cdot wk^{-1}$ at 70–85% of their initial heart rate reserve determined at the time of the baseline exercise test (17). The exercise routine consisted of 10 min of warm-up exercises, 35 min of biking and walking (and eventually jogging), and 10 min of cool-down exercises. Subjects were instructed to maintain their usual diets.

WM group. Participants in the WM group exercised 3–4 $times \cdot wk^{-1}$ following the identical protocol described above. In addition, they also participated in a behavioral weight management program, consisting of approximately 26 weekly 30-min group meetings of three to five participants. The program was derived from the LEARN manual (8). The goal of the intervention was a weight loss of 1 to 2 $lb \cdot wk^{-1}$ brought about by reducing caloric and fat intake through lifestyle changes. Initial dietary goals were set at approximately 1200 $calories \cdot d^{-1}$ for women and 1500 $calories \cdot d^{-1}$ for men, with about 15–20% of calories coming from fat.

CON group. Participants in the CON group maintained their usual dietary and exercise/activity habits until completion of the 6-month evaluation. Subjects were interviewed at monthly intervals to ensure adherence to these conditions. After the 6-month period, subjects were free to engage in exercise, and modify their diets and eating patterns to lose weight if desired.

Data Analysis

Baseline differences among the treatment groups were analyzed using ANOVA for continuous variables and chi-square tests for categorical data. The different physical activities from the daily diary were divided into low, me-

TABLE 1. Sample characteristics by total sample and by group assignment.[a]

Variable	Total Sample (N = 92)	Weight Management (N = 42)	Exercise Only (N = 35)	Control (N = 15)
Blood pressure				
Clinic SBP (mm Hg)	141.5 ± 10.7	143.3 ± 12.3	138.6 ± 8.4	143.2 ± 9.8
Clinic DBP (mm Hg)	93.2 ± 4.7	92.9 ± 5.2	93.4 ± 4.7	93.7 ± 5.0
Ambulatory SBP (mm Hg)	142.2 ± 12.7	142.4 ± 14.5	141.4 ± 11.6	143.4 ± 9.7
Ambulatory DBP (mm Hg)	87.3 ± 6.4	86.6 ± 7.0	87.5 ± 6.3	88.5 ± 4.6
Duration of ambulatory BP monitoring (h)	13.8 ± 2.0	14.0 ± 2.0	13.5 ± 1.3	13.7 ± 3.1
Absolute peak $\dot{V}O_2$ ($L \cdot min^{-1}$)	2.41 ± 0.80	2.35 ± 0.84	2.54 ± 0.74	2.28 ± 0.80
Relative peak $\dot{V}O_2$ ($mL \cdot kg^{-1} \cdot min^{-1}$)	25.9 ± 6.8	25.3 ± 6.5	27.1 ± 6.7	24.4 ± 7.7
Treadmill time (s)	605 ± 139	595 ± 139	629 ± 135	580 ± 152
Weight (kg)	92.7 ± 15.9	91.8 ± 16.4	94.0 ± 14.8	92.2 ± 17.6
Height (m)	1.69 ± 0.09	1.69 ± 0.09	1.70 ± 0.09	1.67 ± 0.10
BMI ($kg \cdot m^{-2}$)	32.2 ± 4.2	32.0 ± 4.1	32.3 ± 3.9	32.9 ± 5.2
Age (yr)	48.0 ± 9.4	49.1 ± 10.3	47.5 ± 8.9	46.1 ± 7.6
Male, No (%)	38 (41%)	16 (38%)	16 (46%)	6 (40%)
Caucasian, No (%)	75 (83%)	38 (91%)	26 (77%)	11 (79%)

[a] Means ± standard deviation.

dium, and high levels of activity on the basis of the amount of effort required to perform the task (19). For example, activities requiring minimal effort, such as watching television or listening to the radio, were classified as low physical activity. Activities requiring substantial physical effort, such as climbing stairs, were classified as high physical activity. Emotions were categorized into high and low emotional responses by summing together the daily diary entries for frustration, sadness, tension, and stress at each ambulatory BP measurement, and then performing a median split by subject to create low and high emotional distress scores.

Repeated measures ANOVA (RM-ANOVA) (22) was used to assess the effects of the interventions on SBP, DBP, HR, and rate pressure product (RPP) responses to physical activity and emotional distress. The first RM-ANOVA used the cardiovascular responses at each level of physical activity as within-subject factors and treatment group as a between-subjects factor. The second RM-ANOVA used the cardiovascular responses at low and high levels of emotion as within-subject factors and treatment group as the between-subjects factor. The Tukey honest significant difference (HSD) test (two-tailed) was used to examine significant main effects. In this manner, it was possible to assess the overall effects of physical activity and emotional distress on cardiovascular functioning and the effects of the treatment group on BP.

RESULTS

Sample characteristics. Of the 133 subjects initially recruited, 112 (84%) completed the study. Only subjects with complete ABP data were included in the analyses. Therefore, data for 92 subjects (42 in the WM group, 35 in the EX group, and 15 in the CON group) were included in this study. This sample was characterized by 59% women and 17% African-American subjects with an average age of 48 yr and a BMI of 32.2 $kg \cdot m^{-2}$. At baseline, the treatment groups did not differ significantly in clinic BP, ABP, peak $\dot{V}O_2$, treadmill time, body weight, BMI (including height and weight), age, gender, and ethnicity (Table 1).

Effects of treatment on aerobic fitness and body weight. At the completion of the intervention, both active treatment groups showed improved aerobic fitness as measured by peak $\dot{V}O_2$ (absolute and relative) and treadmill time as compared with controls. Both the WM group and the EX group had increased $\dot{V}O_2$ (WM group, 6.2 ± 0.6 $mL \cdot kg^{-1} \cdot min^{-1}$; EX group, 3.5 ± 0.7 $mL \cdot kg^{-1} \cdot min^{-1}$) as compared with the CON group (−0.8 ± 1.0 $mL \cdot kg^{-1} \cdot min^{-1}$, $P < 0.001$). The WM group also had significantly longer treadmill times (135.5 ± 11.8 s) as compared with both EX (76.5 ± 11.8 s) and CON groups (−7.7 ± 17.1 s, $P < 0.001$); the EX group also exercised longer than the CON group ($P < 0.001$). Subjects in the WM group also lost significantly more weight (−7.9 ± 0.6 kg) as compared with those in the EX group (−1.8 ± 0.6 kg) and the CON group (0.7 ± 1.0 kg, $P < 0.001$).

Effects of treatment on BP measured during daily life physical activity. At baseline, there were no ABP differences between the three treatment groups. After 6 months of treatment, results of the RM-ANOVA revealed significant physical activity main effects on cardiovascular variables during ambulatory monitoring, with high levels of activity related to increased SBP ($P < 0.0001$), DBP ($P < 0.0001$), HR ($P < 0.0001$), and RPP ($P < 0.0001$). There was also a treatment group main effect for physical activity for DBP ($P < 0.05$), HR ($P = 0.05$), and RPP ($P < 0.01$) but not for SBP ($P = 0.16$). Contrasts of group means for DBP, HR, and RPP at each level of physical activity were performed using the Tukey HSD test. It was found that the WM group, as compared with the CON group, had significantly lower DBP ($P < 0.05$) and RPP ($P < 0.05$) at each level of physical activity and lower HR ($P < 0.05$) with low and medium levels of physical activity. The EX group was found to have lower DBP ($P < 0.05$), HR ($P < 0.05$), and RPP ($P < 0.05$) as compared with the CON group during low levels of physical activity, lower RPP ($P < 0.05$), and a tendency for lower HR ($P < 0.10$) during medium levels of activity, and a tendency to lower DBP ($P < 0.08$) during high levels of physical activity (Fig. 1).

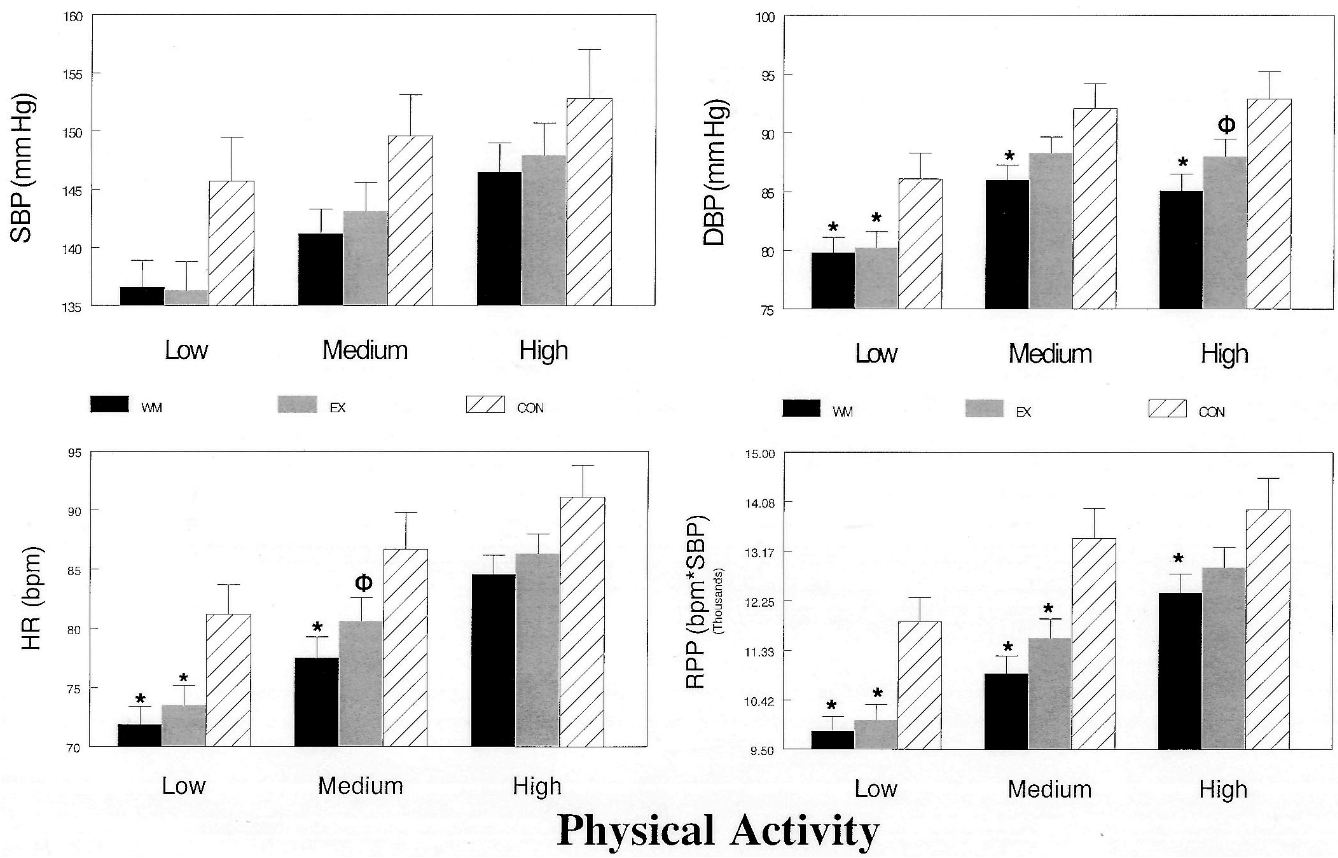

FIGURE 1—ABP and physical activity: Ambulatory systolic blood pressure, diastolic blood pressure, heart rate, and rate pressure product by intervention group and activity level (all measures are mean ± SE). WM, weight management; EX, exercise only; CON, control group. *Contrast between active treatment group (WM or EX) and CON group, $P < 0.05$; $^{\Phi}$contrast between EX and CON group, $P < 0.10$.

Effects of treatment on BP measured during daily life emotional distress. Examination of baseline values revealed no group differences in levels of emotional distress. Results of the RM-ANOVA revealed significant main effects of emotional distress, with high emotional distress related to higher SBP ($P < 0.01$), DBP ($P = 0.001$), HR ($P < 0.01$), and RPP ($P < 0.001$). There also was a treatment group effect for DBP ($P < 0.05$), HR ($P < 0.01$), and RPP ($P = 0.001$), but not for SBP ($P = 0.13$). The Tukey HSD *post hoc* analyses of treatment group effects revealed that the WM group had significantly lower DBP ($P < 0.05$), HR ($P < 0.05$), and RPP ($P < 0.05$) associated with both low and high levels of emotional distress than the CON group. The EX group also had lower DBP, HR, and RPP during low but not during high levels of distress compared with the CON group. During high levels of emotional distress, the EX group tended to have lower RPP than the CON group ($P < 0.07$), but the WM group also had lower HR and RPP (P values < 0.05) compared with the EX group, as well as compared with the CON group (Fig. 2).

DISCUSSION

To our knowledge, this study is the first to examine the effects of exercise and weight loss on BP associated with physical activity and emotional distress during a typical day. As expected, higher intensity physical activity and higher levels of emotional distress were related to elevated BP and HR. A combined exercise and behavioral weight loss program resulted in significantly lower DBP, HR, and RPP levels during high and low physical activities and high and low levels of emotional distress as compared with a control condition. Exercise alone also was associated with reduced BP and HR, but only during low levels of physical activity and distress and not high levels.

Our observations extend laboratory studies of BP by assessing BP during daily life. Exercise training has been shown to reduce BP responses to both exercise and mental stress in laboratory situations (3,4,10,24,35). Increased cardiovascular fitness is related to decreased BP during exercise and faster BP recovery after exercise (33). In a meta-analysis of 34 studies that examined aerobic fitness and psychosocial stressors, Crews and Landers (10) found that aerobically fit subjects had significantly lower BP levels in response to acute laboratory stressors. Several longitudinal studies also have demonstrated decreased BP in response to acute behavioral challenges in normotensive individuals and patients with borderline hypertension (3,4,29). However, these studies failed to take dietary factors into account, and did not adjust for changes in BMI associated with exercise.

The findings of this study indicate that exercise may not be as effective in reducing BP during activities of daily life as is adding weight loss with regular exercise. The combination of exercise and weight loss resulted in significantly

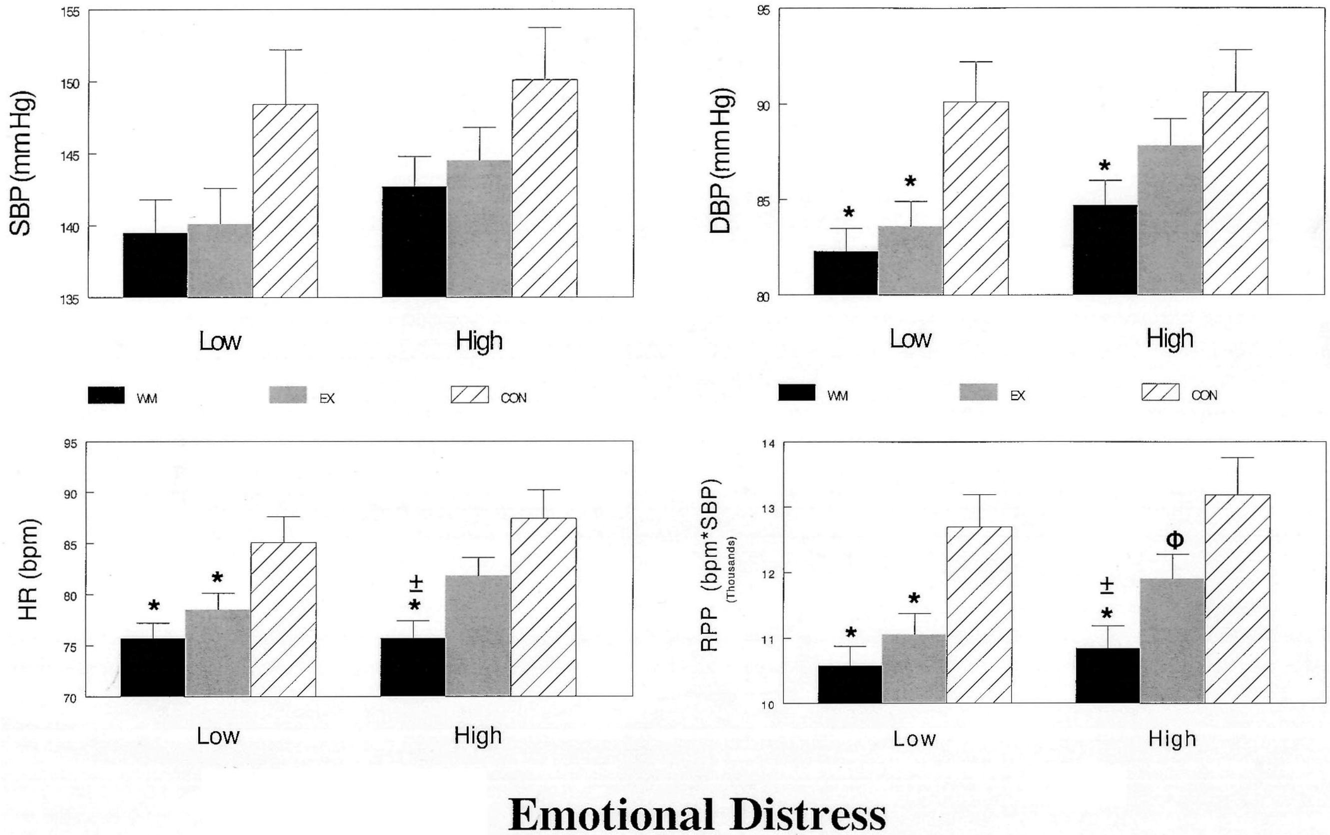

FIGURE 2—ABP and emotional distress: Ambulatory systolic blood pressure, diastolic blood pressure, heart rate, and rate pressure product by intervention group and mood level (all measures are mean ± SE). WM, weight management; EX, exercise only; CON, control group. *Contrast between active treatment group (WM or EX) and CON group, $P < 0.05$; ±contrast between WM and EX group, $P < 0.05$; $^{\Phi}$contrast between EX and CON group, $P < 0.10$.

lower BP across levels of daily physical activities and negative emotions as compared with a waiting list control group. This finding is consistent with a recent study by Cox et al. (9), who found that the effects of exercise on both clinic BP and ABP are most pronounced in the presence of weight loss in a sample of 51 sedentary overweight men with mild hypertension.

In summary, a combined exercise and weight loss program generally resulted in significantly lower BP during activities of daily life than a nonexercising control group. Furthermore, this study has shown that exercise and weight loss are associated with lower BP response during high and low levels of both physical activity and emotional distress during a typical day. Although the clinical significance of these findings is unknown, potential benefits from reductions in daily BP responses could include decreased cardiovascular morbidity and lowered risk for myocardial infarction. Future research might build on these findings by examining the specific physiological pathways by which exercise and weight loss lead to BP changes during daily life.

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