Accumulation of Physical Activity Reduces Blood Pressure in Pre- and Hypertension

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ABSTRACT

PADILLA, J., J. P. WALLACE, and S. PARK. Accumulation of Physical Activity Reduces Blood Pressure in Pre- and Hypertension. Med. Sci. Sports Exerc., Vol. 37, No. 8, pp. 1264–1275, 2005. Purpose: The effectiveness of lifestyle physical activity to reduce BP in prehypertension/hypertension is unclear. The purpose of this study was: 1) to investigate the magnitude and duration of ambulatory BP (AmBP) reduction after the accumulation of one day of lifestyle physical activity (PAaccum) in normotension, prehypertension, and hypertension; and 2) to determine the relationship between energy expenditure (EE) and BP reduction. Methods: Subjects were eight normotensive (112.3/73.1 ± 1.6/1.9 mm Hg), 10 prehypertensive (124.3/79.3 ± 1.2/1.6 mm Hg), and 10 hypertensive (139.7/83.3 ± 3.7/3.7 mm Hg) adults. EE was analyzed during the PA and corresponding control (C) treatment; AmBP was analyzed for 12 h after the PAaccum and corresponding C. EE of the PA (EEPA) was calculated as the total EE for the duration of the PA. Steps to analyze and compare the BP reduction after PAaccum were: 1) determination of the duration of the BP reduction (95% CI), 2) determination of the magnitude of the BP reduction (paired r-tests of C vs PA), 3) determination of the area of the BP reduction, and 4) comparison of the areas (independent t-test) between prehypertension and hypertension. Correlation between EE(EEPA) and BP reduction was examined Results: No BP differences were found for normotension or for DBP in any group. Significant difference in SBP after the PAaccum were: 1) for 8 h; area was significantly different between groups. No correlation was found between EE(EPPA) and BP reduction. Conclusion: The PAaccum reduces SBP in hypertension and prehypertension but does not appear to be related to the EE(EEPA). PAaccum can be utilized as an approach to treat prehypertension and hypertension. Key Words: POSTEXERCISE HYPOTENSION, ACCELEROMETER, DOSE RESPONSE, LIFESTYLE PHYSICAL ACTIVITY

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cientific evidence supports the chronic effects of 20–60 min of dynamic cardiorespiratory exercise, 3–5 d · wk⁻¹ at 40–70% intensity in the treatment of hypertension (16,25). More recently, however, the accumulation of moderate physical activity on most, if not all, days of the week has been recommended as the exercise treatment for hypertension (2,16) as well as for the prevention of hypertension progressing to hypertension (2). The scientific evidence existing to support this position stand is limited, specifically on the use of physical activity and its accumulation for the treatment of hypertension. Physical activity is defined as any bodily movement resulting from the contraction of the skeletal muscles (25). Lifestyle physical activity has been defined as the daily accumulation of at least 30 min of self-selected activities, which includes all leisure, occupational, or household activities that are at least moderate to vigorous in their intensity (5). The role of physical activity in all cause morbidity and mortality has been well established through epidemiological methods (10,12).

There are a total of 74 groups comprising 1284 patients in clinical trials investigating the role of traditional exercise in blood pressure reduction (9). The only clinical trial investigating physical activity as treatment for hypertension was that of Moreau and colleagues (13), who reported a reduction in blood pressure in stage 1 hypertensive subjects after a 24-wk walking program (some accumulated) designed to increase walking 3 km · wk⁻¹. The efficacy of traditional exercise on subjects with normal to high blood pressure has been well established by seven groups of investigators who utilized 578 subjects (7). In terms of physical activity, two studies exist observing subjects with normal to high blood pressure reduction (9). The only clinical trial investigating physical activity as treatment for hypertension was that of Moreau and colleagues (13), who reported a reduction in blood pressure in stage 1 hypertensive subjects after a 24-wk walking program (some accumulated) designed to increase walking 3 km · wk⁻¹. The efficacy of traditional exercise on subjects with normal to high blood pressure has been well established by seven groups of investigators who utilized 578 subjects (7). In terms of physical activity, two studies exist observing subjects with normal to high blood pressures. Although not statistically significant, Murphy and Hardman (14) found the reduction in systolic blood pressure to be greater for women who walked three short 10-min bouts (−7.4 ± 7.3 mm Hg) than for those who walked one long 30-min bout (−4.6 ± 5.9 mm Hg) at 70–80% for 10 wk. Dunn and colleagues (6) reported a similar reduction in systolic and diastolic blood pressures for adults who engaged in lifestyle physical activity (−3.63/
5.38 mm Hg) versus structured exercise (-3.26/5.14 mm Hg) for 24 months. The energy expenditure goal for the physical activity (accumulation of 30 min of any type of activity) was an increase in energy expenditure of 2 kcal·kg⁻¹·d⁻¹, whereas for the structured exercise group (50–85\% of \( \dot{V}O_2 \) peak at 20–60 min) it was an increase of 3 kcal·kg⁻¹·d⁻¹. No studies exist investigating the role of physical activity in the treatment of prehypertensive adults because the classification of prehypertension is new (2).

It is difficult to attribute any single component of exercise or physical activity to a resultant blood pressure reduction. However, energy expenditure is the most common denominator in describing both exercise and physical activity and may be the single variable most related to a blood pressure reduction. In a meta-analysis of 57 exercise training studies, Fagard (7) found no correlation between the energy expenditure and the reduction in systolic (\( r = 0.14 \)) or diastolic (\( r = -0.02 \)) blood pressure. No study exists relating the energy expenditure of physical activity and blood pressure reduction.

The role of the accumulation of physical activity, specifically lifestyle physical activity, in the treatment of prehypertension and hypertension has not been well established. Thus, the purpose of this study was: 1) to investigate the magnitude and duration of ambulatory blood pressure reduction after 1 d of lifestyle physical activity in normotensive, prehypertensive, and hypertensive adults; and 2) to determine the relationship between the energy expenditure and the blood pressure reduction. It was hypothesized that: 1) 1 d of lifestyle physical activity will reduce ambulatory blood pressure in prehypertensive and hypertensive adults, and 2) the reduction in blood pressure will be directly related to the energy expenditure of the physical activity accumulated.

METHODS

A repeated measures experimental design with two treatments, 2–7 d apart, was given to three different groups of subjects: normotensive, prehypertensive, and hypertensive adults. One treatment consisted of the accumulation of physical activity over an 8- to 12-h period, and the other was a control period of the same time on a separate day. Beginning at 0700 h, physical activity was measured using a three-dimensional accelerometer, and blood pressure was measured by ambulatory monitoring for the next 24 h. Figure 1 illustrates the energy expenditure and systolic blood pressure data collected on a representative prehypertensive subject. The physical activity period was considered to be the first 8–12 h when the subject was performing or accumulating the physical activity (left panels of Fig. 1), whereas the second period was the time after physical activity (right panels of Fig. 1). The physical activity data used in this study were from 0700 h to the end of the accumulation of physical activity (lower left panel of Fig. 1). Although ambulatory blood pressures were recorded for 24 h during both treatment days, only the period of time after the end of the accumulation of physical activity (lower left panel of Fig. 1). The physical activity data used in this study were from 0700 h to the end of the accumulation of physical activity (right panels of Fig. 1). The physical activity data used in this study were from 0700 h to the end of the accumulation of physical activity (determined individually for each subject) was analyzed as the acute response to the physical activity (upper right panel of Fig. 1). Activities performed throughout the day were recorded in an activity diary. All procedures were previously approved by the Indiana University committee for the protection of human subjects.
Subjects. Subjects were eight normotensive (N) adults, 10 prehypertensive (P) adults, and 10 hypertensive (H) adults. All were experienced in exercise and/or physical activity. Demographics of these subjects are presented in Table 1. Prehypertensive subjects were defined by one of the following (2): 1) having a mean systolic blood pressure ≥120 mm Hg and <140 mm Hg, or 2) having a mean diastolic blood pressure ≥80 mm Hg and <90 mm Hg measured by auscultation. Hypertensive subjects were defined by one of the following (2): 1) having had a previous diagnosis of hypertension by a primary physician, or 2) having a mean systolic blood pressure >140 mm Hg and/or a mean diastolic blood pressure >90 mm Hg measured by auscultation. Exclusion criteria included: 1) known coronary artery disease, 2) orthopedic limitations for performing physical activity, and 3) obesity to the extent that the ambulatory monitor could not fit the subject properly. Hypertensive subjects continued to take antihypertensive medications for this study. Before the study, an approved informed consent was explained and signed by the subjects.

Procedures. The procedures of the study consisted of 1) completing the Par-Q health questionnaire, 2) recording each activity in the activity diary. The subject was scheduled to come to the laboratory 30 min before the 24-h data collection starting (0700 h), and the time span between the two treatments ranged from 2 to 7 d. The subject was instructed to record each activity in the activity diary. The time to place the ambulatory blood pressure monitor and measurement was established according to subject’s convenience, the order was equally distributed among the three groups. Both the physical activity and control treatments began at the same time of day (0700 h), and the time span between the two treatments was 7 d. The subject was scheduled to come to the laboratory 30 min before the 24-h data collection starting time to place the ambulatory blood pressure monitor and motion sensor and to instruct the subject about the treatment, instruments, and how to fill out the activity diary.

Control treatment. Subjects participated in their usual activities of daily living. Subjects were asked to record and duration of activities in the activity diary and were instructed to abstain from physical activity, exercise, and sports.

Physical activity treatment. Subjects were instructed to add physical activity to their daily routine. A variety of home and gardening activities such as splitting logs, mowing the lawn (walking), digging/spading, tilling, raking, laying sod, and brisk walking have been identified as meeting the physical activity requirement (1). The subjects were instructed to record each activity in the activity diary. The target volume of physical activity was an accumulation of 150 kcal·d⁻¹ (23). The types of physical activities were discussed and agreed to before the beginning of the physical activity treatment.

Energy expenditure of physical activity. Two instruments, one objective and one subjective, were used to quantify the physical activity and energy expenditure. An RT3 accelerometer (Stayhealthy Inc., Monrovia, CA) was used to measure 24-h activity in all subjects. RT3, the latest version of Tritrac, is a battery powered three-dimensional (triaxial) accelerometer (18,20). RT3, firmly attached to a belt on the hip at the anterior axillary line of the dominant leg, records data in three axes, and contains three separate accelerometers, positioned internally at 90° to one another.
It measures motion as acceleration of the body. Thus, intensity of movement is reflected in the instrument’s output. Output from each accelerometer is reported along with a composite three-dimensional signal called the vector magnitude. The software also provides an estimation of activity and total energy expenditure based on the subject’s age, height, weight, and gender. RT3 was programmed (using mode 3) to sample data every second and average this data over 1-min periods for 24 h. Therefore, kilocalorie-per-minute values were obtained every minute.

The activity diary was used to report mode and duration (minutes) of activities performed during 24 h. Different activity diaries were used for the physical activity and control treatments. For both days, we asked 1) time of sleep and 2) predominant activities of daily living performed. For the physical activity treatment, we also asked 1) type of physical activity and 2) starting and ending time of each bout of physical activity performed.

Ambulatory blood pressure measurement. Accutraker II (Suntech Medical Instruments, Inc., Raleigh, NC) was used to measure the 24-h ambulatory blood pressure in all subjects. The nondominant arm was used for all subjects. The Accutraker II was programmed to take a measurement every 15 ± 5 min for daytime hours (0600 to 2200 h) and every 30 ± 5 min for nighttime hours (2200 to 0600 h). One repeat measurement was taken if the first measurement was unsuccessful during the daytime hours and two repeat measurements were taken during the nighttime hours if the first measurement was unsuccessful. The inflation of the cuff for each measurement was 30 mm Hg greater than the previous reading. The cuff deflation rate was set at 3 mm Hg·s⁻¹. Subjects were instructed 1) to abstain from exercise, 2) not to take a shower, 3) to relax and straighten out the arm during the blood pressure measurement, 4) to remove the accelerometer during sleeping period, 5) to replace the accelerometer to the correct location upon waking, and 6) to remove devices and turn off the ambulatory blood pressure monitor after the 24-h period.

Data processing. The energy expenditure from 0700 h to the end of the physical activity was used to represent the energy expenditure for both the control and physical activity treatments. The determination of the end of physical activity is explained in the next section. The blood pressure data of interest for this investigation were the 12 h after the end of physical activity.

Physical activity and energy expenditure data. For each test, accelerometer data were downloaded to the computer using Stayhealthy software and transferred and saved to a Microsoft Excel 0.5/95 spreadsheet. The energy expenditure of the control treatment (EEc), the energy expenditure of each bout of physical activity (EEB), the total energy expenditure for the accumulation of the physical activity (EEPA), and the total duration of the accumulation of physical activity (PAmin) were measured from the activity diary. EEc (kcal) was calculated as the energy expenditure (base-line) during the waking hours (average + 1 SD) of the control treatment. A bout of physical activity was defined as any energy expenditure above EEc. EEB (kcal) was calculated as the total energy expenditure for that bout. The last hour of physical activity when the energy expenditure was greater than the EEc was considered the end of the accumulation of physical activity. The EEPA was the sum of each EE for the duration of the accumulation of the physical activity. PAmin was the sum of the duration of each bout of physical activity. The PAmin (kcal-min⁻¹) was calculated as EEPA/PAmin. When the EEPA was 150 kcal above EEc (EEPA,EEc), the criteria for physical activity was met for the subject. The mode and frequency of physical activity bouts were measured from the activity diary.

Ambulatory blood pressure data. For each test, ambulatory blood pressure data were downloaded to the computer using AccuWin Pro v2.3 software. Data were manually reviewed for missing and erroneous readings. Readings were purged if 1) data were missing; 2) systolic blood pressure was lower than diastolic blood pressure; 3) systolic blood pressure was >240 mm Hg or <50 mm Hg; 4) diastolic blood pressure was >140 mm Hg or <40 mm Hg; 5) heart rate was >150 beats·min⁻¹ or <40 beats·min⁻¹; 6) systolic blood pressure and diastolic blood pressure deviation ±50 and ±20 mm Hg, respectively, from the surrounding values; and 7) heart rate deviated ±30 beats·min⁻¹ from the surrounding values as previously described (24). For each subject, systolic blood pressure and diastolic blood pressure was averaged every hour.

Four steps were utilized to analyze and compare the blood pressure reduction after physical activity: 1) determination of the duration of the blood pressure reduction, 2) determination of the magnitude of the blood pressure reduction, 3) determination of the area of the blood pressure reduction, and 4) comparison of the areas among the groups. These four steps were completed on blood pressure variables demonstrating differences from the control treatment.

The duration of the blood pressure reduction was determined by calculating the accumulation of the blood pressure reduction over time with the following formula:

\[
\text{Accumulation of SBP reduction} = \sum_{i=1}^{n} \{(SBP_{\text{CONTROL}} - SBP_{\text{PA}})\}, \quad i = \text{time h}
\]

This accumulated reduction was then plotted for each hour (Fig. 2) with the 95% confidence limits for the initial slope. The duration of the blood pressure reduction was considered to be the time period in which the blood pressure reduction remained within the 95% confidence limits of the regression of the initial slope of this relationship. It is possible for each group to have a different duration of reduction using this technique.

The magnitude of the blood pressure reduction was based on the corresponding duration of the blood pressure reduction found in the previous step. The blood pressures were averaged over the time period determined as the appropriate duration for both the control and physical activity treatments for each group. The difference in these average blood pressures between the control and physical activity treatments was considered the magnitude of the blood pressure reduction.
The area under the blood pressure curve was defined as the area between the control and physical activity blood pressure curves for the duration of the blood pressure reduction. The area between the blood pressure curve and the time axis (x axis) was calculated by summing the area of successive trapezoids, corresponding to each blood pressure reading. The total area under the control curve was subtracted from the total area below the physical activity curve to obtain the area between the two curves. The areas between the control and physical activity blood pressure curves were used to compare the efficacy of the treatment among the groups.

Statistical analysis. Data are expressed as mean ± standard error of the mean (SEM). Descriptive statistics were used for the demographics of the subjects, and an analysis of variance (ANOVA) was used to compare the three groups. Tukey post hoc test was used when significant differences were found. Paired t-tests (control vs physical activity treatments) were used to test the significance of the magnitude of the blood pressure reduction for each group. An independent t-test was performed to compare the blood pressure area of reduction between the groups that demonstrated a significant magnitude of blood pressure reduction (i.e., the prehypertensive and hypertensive groups). Pearson correlations were used to investigate the relationship between independent variables (i.e., BMI, age, etc.) and dependent variables (the magnitude and area of blood pressure reduction). Dependent variables were reexamined with covariates when significant correlations were found. Pearson correlation was used to investigate the relationship between the energy expenditure of the accumulation of physical activity (kcal) and the reduction in systolic and/or diastolic blood pressures (mm Hg) for each group. For all statistical tests, the alpha level was set at 0.05. Statistical analyses were performed with SPSS v.11.0f.

RESULTS

Subjects. The demographics of the subjects for each group are summarized in Table 1. Significant differences were found in: 1) age, BMI, and screening diastolic blood pressures between normotensive and hypertensive groups; and 2) for screening systolic blood pressures among all three of the groups. Data were further examined with BMI and age as covariates because significant differences were found in BMI and age among the groups. Screening systolic blood pressures remained significantly different among the three groups accounting for differences in BMI and age ($F = 25.907; p = 0.0001$). Only one subject was sedentary.

Time of day for starting the 24-h data collection was at 0740 ± 0015 h for the normotensive group, 0749 ± 0014 h for the prehypertensive group, and 0710 ± 0009 h for the hypertensive group. The difference between the times of day for the two treatments was 0018 ± 0008 min for the normotensive group, 0011 ± 0009 min for the prehypertensive group, and 0012 ± 0004 min for the hypertensive group. The length of time between the two treatments was 6.0 ± 0.6 d for the normotensive group, 4.1 ± 0.6 d for the prehypertensive group, and 3.9 ± 0.7 d for the hypertensive group. Four of eight subjects (50%) in the normotensive group, 6 of 10 (60%) in the prehypertensive group, and 6 of 10 (60%) in the hypertensive group started with the control treatment, whereas the remainder started with the physical activity treatment. Two of the 10 prehypertensive subjects (20%) did not meet the energy expenditure criteria of 150 kcal of physical activity (noncompliers). The rate of blood pressure acquisition (measurements per hour) was similar between the control (N = 3.3 ± 0.1; P = 3.1 ± 0.2; H = 3.6 ± 0.2) and physical activity (N = 3.4 ± 0.1; P = 3.2 ± 0.1; H = 3.3 ± 0.1) treatments.

Physical activity. The energy expenditure for both the physical activity period and the time after the physical activity period is illustrated in the lower panels of Figures 3–5 for the physical activity and control treatments for all three groups. The collection of energy expenditure data for

![Diagram](https://example.com/diagram.png)
the time period after the physical activity period was discontinued when the subject went to sleep and does not extend to the same time period the blood pressure was measured. Table 2 summarizes the total energy expenditure, total accumulated duration, and intensity of physical activity treatment for each group. The noncompliers were excluded from this analysis of the energy expenditure data. Although the energy expenditure of the physical activity treatment was not significantly higher than the control treatment ($F = 0.839; P = 0.444$), the criterion 150-kcal difference was met and was not significantly different among the three groups (one-way ANOVA with repeated measures; $F = 2.475; P = 0.105$). In addition, no significant differences were found among the three groups for total duration and intensity of physical activity. Table 3 summarizes the distribution of the modes and frequencies of the physical activities performed for each group during the physical activity treatment. All the activities were distributed among the three groups indicating similar types of activities for each.

Blood pressure reduction. The two subjects who did not reach the target energy expenditure of 150 kcal were omitted from the analysis of the blood pressure reduction. The hourly systolic blood pressures for the physical activity period and the 12 h after physical activity are illustrated in the upper panels of Figures 3–5 for all three groups. Figure 2 illustrates the regression (with 95% confidence limits) of the initial slope of blood pressure reduction and the remaining hourly blood pressures. A blood pressure reduction was found only in the prehypertensive and hypertensive groups as illustrated in Figure 2. The findings of no reduction in the normotensive group was confirmed by comparing the average 12-h blood pressures between the two treatments (control = 105.0 ± 2.2 mm Hg vs physical activity = 105.5 ± 3.1 mm Hg). The duration of the blood pressure reduction was found to be 6 h for prehypertension and 8 h for hypertension.

The magnitude of the blood pressure reduction was 6.6 ± 2.3 mm Hg for the 6 h for the prehypertensive group and 12.9 ± 4.3 mm Hg for the 8 h for the hypertensive group. The magnitude of these blood pressure reductions were significant in both the prehypertensive ($t = 2.864; P = 0.024$) and hypertensive ($t = 2.819; P = 0.023$) groups, as detected by paired $t$-tests of control versus physical activity, respectively.

The area between the control and physical activity treatment curves is illustrated in Figures 4 and 5. The area between the control and physical activity treatment curves was found to be significantly different between prehypertensive (21.7 ± 15.2 mm Hg·h$^{-1}$) and hypertensive (123.4 ± 42.8 mm Hg·h$^{-1}$) groups based on independent $t$-tests ($t = -2.263; P = 0.044$). The magnitude of blood pressure reduction was not significantly correlated with either BMI ($r = 0.214; P = 0.393$) or age ($r = 0.180; P = 0.476$). Similarly, Pearson correlations between area of blood pressure reduction and BMI ($r = 0.115; P = 0.648$) or age ($r = 0.634; P = 0.137$) were not significant. Therefore, data were not reexamined with BMI and age as covariates for neither the magnitude nor the area of blood pressure reduction.

Relationship between the energy expenditure of physical activity and the reduction in blood pressure. Figure 6 illustrates the relationship between energy expenditure and blood pressure reduction for prehypertension, hypertension and for the combined pre- and hyperten-
sive groups. Data from the noncompliers were included in these correlations. No significant correlations were found between the EE(PA-C) and the reduction in systolic blood pressure for prehypertension \( r = -0.09; N = 10 \), or hypertension \( r = 0.09; N = 10 \), or in combined pre- and hypertensive groups \( r = 0.08; N = 20 \).

**DISCUSSION**

The purpose of this study was: 1) to investigate the magnitude and duration of ambulatory blood pressure reduction after 1 d of lifestyle physical activity in normotensive, prehypertensive, and hypertensive adults; and 2) to determine the relationship between the energy expenditure and the blood pressure reduction. Twelve-hour ambulatory blood pressures after lifestyle physical activity were compared with the same period of time after a control treatment. As expected, no blood pressure reductions were found in normotensive subjects. A significant reduction in systolic blood pressure was found for 6 h for the prehypertensive group (6.6 ± 2.3 mm Hg) and for 8 h for the hypertensive group (12.9 ± 4.3 mm Hg) after the accumulation of physical activity. However, neither of the systolic blood pressure reductions found in prehypertensive or hypertensive adults were correlated with the energy expenditure of the physical activity. The inclusion of prehypertensive subjects and the investigation of 1-d lifestyle physical activity are the first unique aspects of this study.

This is the first study of its kind to target prehypertensive subjects. Prehypertension has been identified as a critical population for the intervention to prevent progression to hypertension (26). Lifestyle modification, including the accumulation of physical activity, is the only recommended treatment at this time (2). Thus, the observation of physical activity for prehypertensive subjects is warranted.

A 1-d lifestyle physical activity was chosen for this study because it may be the initial step to investigate the effectiveness of physical activity on blood pressure reduction (22). Training or long-term treatment studies may not be justified without first demonstrating an acute response. The use of an acute approach is justified in this investigation because existing long-term studies of physical activity as a treatment of blood pressure (13) are limited. Furthermore, the utilization of acute responses allows for a more efficacious study of possible variations in the accumulation of physical activity in the treatment of hypertension. The acute effects are considered to contribute to the chronic training effects (22). Finding a blood pressure reduction after a single day of physical activity is advantageous for the inactive patient, considering the immediate results may be motivating to continue incorporating lifestyle physical activity into their daily routine.

Although our blood pressure screening protocol conformed to the recommendations of the World Health Organization (29), two screening days to classify subjects as prehypertensive or hypertensive may be considered a limi-

![Image](http://www.acsm-msse.org)
tation of our study. On the other hand, the ambulatory data supported the classification of the hypertensive subjects. The average daytime blood pressures (0600–2200 h) in the control treatment for the hypertensive patients was 136.3/77.0 mm Hg, which is higher than the 135/85 mm Hg criteria for hypertension using ambulatory blood pressure monitoring (19). No standards exist for ambulatory pressures in prehypertension; however, the average daytime blood pressure for the prehypertensive group was 121.8/74.1 mm Hg.

**Subjects.** The demographics of the prehypertensive group cannot be compared with the literature because this is the first study of its kind to include prehypertensive subjects. The hypertensive subjects in this study were not different from those reported in other blood pressure studies (15,24) except for taking antihypertensive medications. The use of the antihypertensive medications is probably responsible for the lower screening pressures found in the hypertensive group. The subjects were tested on their medications to simulate real-world conditions even though it may be considered a limitation of our study. According to the literature (4,8,11), when exercise/physical activity is combined with antihypertensive medication, there is no additive blood pressure reduction. Even though the use of antihypertensive medications may not confound the results found in training studies, the acute interaction of medications and physical activity on blood pressure reduction is unknown.

The treatment order was based on subject’s preference so that the subjects could incorporate their physical activity in a single day. Sixty percent of the subjects began with the control treatment, whereas 40% of subjects began with the physical activity treatment. There were no order effects on the blood pressure reduction using independent t-test ($t = -0.092; P = 0.928$).

Overall, 96% of the subjects were experienced in exercise; 39% were participants in the Indiana University Adult

<table>
<thead>
<tr>
<th>TABLE 2. Total accumulated duration, total energy expenditure, and intensity of the physical activity treatment (mean ± SEM).</th>
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<tbody>
<tr>
<td>Control Treatment</td>
</tr>
<tr>
<td>---------------------------------</td>
</tr>
<tr>
<td>Total duration (min)</td>
</tr>
<tr>
<td>Normotension</td>
</tr>
<tr>
<td>Prehypertension</td>
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<tr>
<td>Hypertension</td>
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<tr>
<td>Energy expenditure for the accumulation of physical activity</td>
</tr>
<tr>
<td>Intensity (kcal · min⁻¹)</td>
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<tr>
<td>Normotension</td>
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<tr>
<td>Prehypertension</td>
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<td>Hypertension</td>
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<tr>
<td>Total above baseline control (kcal)</td>
</tr>
<tr>
<td>Normotension</td>
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<td>Prehypertension</td>
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<td>Hypertension</td>
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**FIGURE 5**—Energy expenditure (mean ± SEM) and systolic blood pressure (mean ± SEM) for the period of physical activity (left panels) and for the time after the accumulation of physical activity (right panels) for hypertensive adults. The shaded areas in the upper right panel illustrate the area of blood pressure reduction after physical activity. Each time period is standardized to begin at time zero.
TABLE 3. Types and frequency of physical activities performed.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Normotension (N = 6)</th>
<th>Prehypertension (N = 10)</th>
<th>Hypertension (N = 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bicycling</td>
<td>7</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Brisk walking</td>
<td>8</td>
<td>5</td>
<td>16</td>
</tr>
<tr>
<td>Carrying heavy objects</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Cleaning the house</td>
<td>6</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Climbing stairs</td>
<td>3</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Gardening</td>
<td>8</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td>Mowing the lawn</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Fitness Program, and the rest of the subjects reported to be currently exercising (on the PAR-Q). Two of the 28 subjects (7%) who did not comply with the target energy expenditure of 150 kcal were experienced in exercise; both were women and both were prehypertensive. The discrepancy must have been in their physical activities because the energy expenditures of their control treatment (1.6 ± 0.3 and 1.2 ± 0.1 kcal·min⁻¹) were not different from the compliers (1.6 ± 0.5 kcal·min⁻¹). The physical activities of noncomplier number 1 were climbing stairs (fq = 5), cleaning (fq = 1), and bicycling (fq = 1), which added up to 109 kcal above the control. The physical activities of noncomplier number 2 were climbing stairs (fq = 1), carrying groceries (fq = 1), cleaning (fq = 1), and gardening (fq = 1), which added up to 133 kcal above control. These noncompliers either did not perform enough physical activity or the accelerometer was unable to quantify their activities.

**Blood pressure reduction.** The uses of the area between the control and physical activity blood pressure curves as well as the determination of the duration of blood pressure reduction were additional unique aspects of this study. The area is a good representation of the total pressure reduction were additional unique aspects of this study. The area is a good representation of the total reduction in blood pressure after a single exercise treatment has been reported to be 5–8 mm Hg for 11–12 h in systolic and 6–8 mm Hg for 6–8 h for diastolic blood pressure (25).

The duration reported in our study was based on the cessation of the blood pressure reduction. We could have easily found significant reductions in average blood pressures beyond the 6- and 8-h periods, which would have inflated the durations and diminished the magnitudes. For example, had we averaged the blood pressure for 12 h instead of 8 h, we could have reported a significant reduction of 8.8 ± 3.1 mm Hg for 12 h for the hypertensive group instead of the 12.9 ± 4.3 mm Hg found for the 8-h reduction. This inflation of the duration and the diminution of magnitude would be because the initial blood pressure reduction was large enough to spread to subsequent time periods even though it did not reflect the period of time of the true blood pressure reduction.

Another source for the shorter duration of the blood pressure reduction may be attributed to the time of day. The ambulatory blood pressure measurements after the physical activity period began at 1737 ± 0031 h for hypertensive group and 1806 ± 0031 h for hypertensive group. The simple consequence of going to sleep may have compromised the duration of the blood pressure reduction because sleeping blood pressures are generally lower than waking blood pressures (2). The mean beginning sleep time was 2222 ± 0024 h for prehypertensive group and 2342 ±...
tensive subjects (118.7 ± 4.20 mm Hg) exhibited a greater blood pressure reduction than prehypertensive subjects (137.3 ± 5.2 mm Hg) for the hypertensive group; neither group had significantly different sleeping blood pressures after the physical activity treatment (P = 0.591); H = 120.8 ± 4.25 mm Hg (t = −1.02; P = 0.336). These findings are consistent with other results in our laboratory in that patients who exhibit normal sleeping blood pressures do not reduce sleeping blood pressure after an exercise treatment (unpublished data).

Finding differences in blood pressure reduction among the three groups was expected because the magnitude of a blood pressure reduction after exercise is dependent on the previous blood pressure. That is, patients who present with greater blood pressures during the physical activity treatment was significantly different from the corresponding control treatment (NC = 114.1 ± 2.26 mm Hg to N PA = 117.4 ± 2.61 mm Hg (t = −2.07; P = 0.078); PC = 121.4 ± 1.85 mm Hg to P PA = 124.0 ± 2.37 mm Hg (t = −1.38; P = 0.20); H C = 134.2 ± 5.74 mm Hg to H PA = 134.4 ± 6.57 mm Hg (t = −0.061; P = 0.95)). It was not unexpected for the average activity pressures to be higher because upper body work elicits a higher blood pressure response than lower body work. However, less than 50% of the activities were upper body activities, spread out over 10–11 h, which appears to be undetectable in these means. Thus, not only does physical activity demonstrate a slight increase in blood pressure during the treatment, but it also appears to be as effective in reducing blood pressure after the treatment as traditional exercise (9,25).

**Caloric cost of the physical activity.** Two measurements of physical activity were utilized in this study: an activity diary and the accelerometer. Subjects were asked to record mode and duration of the physical activity in the diary. The subjects adhered very well to recording the types of physical activities in the diary each time they were performed; however, the duration of physical activity was not well documented. Thus, energy expenditure could only be estimated from the accelerometer.

The intention of this study was to simulate the lifestyle physical activity recommended in the guidelines reported in the Surgeon General Report on Physical Activity (23) as well as the American College of Sports Medicine (16). That is, the accumulation of physical activity on most, if not all, days of the week. An energy expenditure of 150 kcal·d⁻¹ was reported as the minimum criterion to obtain health benefits (23). In our study, the total energy expenditure of the physical activity appeared to be approximately four times greater than the recommendations of the Surgeon General’s report, most likely because the duration of the accumulation of physical activity exceeded 4 h.

The long duration as well as some of the modes of lifestyle physical activity accumulated throughout the day by subjects in this study may be more applicable for weekends, days off, or in stages of life in which the subject has longer periods of time, such as retirement. In any case, these types of scenarios can be incorporated into some aspects of daily living as an alternative to exercise with effectiveness in lowering blood pressure and can be integrated into programs utilizing a variety of physical activity strategies to lower blood pressure. Further investigation needs to be conducted to investigate whether the accumulation of less than 1 h and more applicable daily physical activity could have the same beneficial effect on lowering blood pressure as well as the reproducibility of such activities.

The intensity of the physical activity measured by the accelerometer (4.0–5.0 kcal·min⁻¹) appeared to be 30–50% below the estimated energy expenditure for the types of physical activities recorded. The most common activities reported by our subjects were brisk walking, gardening, and mowing the lawn, which according to Ainsworth and colleagues (1) should exhibit energy expenditures of 6.6, 4.5, and 9.3 kcal·min⁻¹, respectively (for the average weight of our subjects). These discrepancies may be due to: 1) the accuracy of the activity diary or 2) the utilization of the RT3 accelerometer. Most subjects failed to accurately record the duration of each activity they performed. The only way we could obtain activity duration was by the accelerometer data.

The RT3 accelerometer was used in this study because the nature of physical activity is three dimensional. Two dimensional accelerometers adequately monitor walking or cycling, but our subjects were instructed to engage in all types of physical activity in which a three-dimensional accelerometer would be more suitable (27). On the other hand, the motion sensor RT3, although being the latest version of three-dimensional accelerometers, still appears to have some limitations (18,20). Like all types of accelerometers, the accuracy of the estimation of the energy expenditure may depend on the type of physical activity. When the motion sensor is worn at the hip, the estimation of energy expenditure for locomotion has been demonstrated to be accurate (27). However, the accelerometer appears to underestimate the energy expenditure for upper-body activities such as cleaning windows or gardening. Overall, the motion...
sensor RT3 underestimates energy expenditure between 30 and 70% in field conditions (27). In our study, 42.5% of the physical activities recorded on the activity diary were upper-body related (carrying heavy objects, cleaning, gardening). Thus, the accelerometer may not have estimated the energy expenditure accurately.

**Relationship between energy expenditure and blood pressure reduction.** No correlations between the energy expenditure and the reduction in blood pressure were found in our study. The primary correlations between energy expenditure and blood pressure reduction were performed on each group separately because the blood pressure reduction among the three groups was significantly different, yet the energy expenditures were not. Combining the groups would have compromised the correlations as illustrated in Figure 6 in the combined data. In any case, the lack of a significant relationship between energy expenditure and blood pressure reduction found in this study was also found by Fagard (7), who, in a meta-analysis of 57 training studies, found no correlation between the energy expenditure and the reduction in systolic (r = 0.14) or diastolic (r = −0.02) blood pressure.

In terms of clinical significance, the type of lifestyle physical activity investigated in this study appears to be as effective in lowering blood pressure as traditional cardiorespiratory exercise. Yet these lifestyle activities may be considered even more effective in lowering blood pressure than exercise considering that the adherence to lifestyle activities appear to be correlated with the energy expenditure of the physical activity. The activities, as utilized in this study, can be incorporated into some aspects of daily living with effectiveness in lowering blood pressure and can be integrated into programs utilizing a variety of physical activity strategies to lower blood pressure. Further investigation needs to be conducted to investigate whether the accumulation of less (<1 h) and more applicable physical activity could have the same beneficial effect on lowering blood pressure.

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