Physical Activity in Young Adults and Incident Hypertension Over 15 Years of Follow-Up: The CARDIA Study

Emily D. Parker, MPH, Kathryn H. Schmitz, PhD, MPH, David R. Jacobs, Jr, PhD, Donald R. Dengel, PhD, and Pamela J. Schreiner, PhD

METHODS

Study Population
The CARDIA study is an ongoing, multicenter, longitudinal investigation of the evolution of coronary heart disease risk factors during young adulthood. Participants were recruited at random from community areas of Birmingham, Ala; Chicago, Ill; and Minneapolis, Minn; and from the Kaiser-Permanente health plan in Oakland, Calif. In 1985 to 1986, 5,115 participants were recruited and balanced by gender, race (Black, White), education (high-school graduate or less, greater than high school), and age (18–24 years old, 25–30 years old). Other eligibility criteria included permanent residence in the target area and freedom from both chronic disease and disability at baseline. Further details of the recruitment strategy and baseline characteristics have been described elsewhere. Six examinations of the cohort were made: baseline (1985–1986) and 2, 5, 7, 10, and 15 years later, with retention of 91%, 86%, 81%, 79%, and 74% of the cohort, respectively. The Coordinating Center and the CARDIA Quality Control Committee monitored quality of data collection.

Analyses to estimate incidence of hypertension were based on 3,993 men and women. The exclusions were 146 people who had hypertension at baseline, 789 people who had missing blood pressure data at more than 2 follow-up exams, and 333 people who were missing data for any other covariates. In addition, if a woman self-reported pregnancy at a specific examination, her blood pressure and physical activity data for that examination were not included (n = 21 excluded observations). In general, there were small differences between CARDIA participants included in these analyses and those excluded. Participants included in these analyses were less likely to be Black (50.0% vs 64.2% of excluded; P < .001), reported more years of education (mean of 14.6 years vs 13.9 years among excluded; P < .001), reported lower prevalence of smoking (28.8% vs 36.6% of excluded; P < .001), had lower body mass index (BMI; mean of 24.3 kg/m² vs 25.1 kg/m² among excluded; P < .002), and had lower blood pressure (systolic 109.7 mm Hg vs 113.2 mm Hg among

Objective. We sought to examine the relation between physical activity and incident hypertension in young adults over 15 years of follow-up in the Coronary Artery Risk Development in Young Adults study.

Methods. A total of 3,993 Black and White men and women aged 18 to 30 years were examined at baseline, and 2, 5, 7, 10, and 15 years later. Blood pressure and physical activity were measured at each exam. Hypertension was defined as systolic 140 mm Hg or higher, diastolic 90 mm Hg or higher, or antihypertensive medication use. Average physical activity and incident hypertension over 15 years of follow-up were analyzed.

Results. There were 634 cases of incident hypertension over 15 years of follow-up. Those who were more versus less physically active experienced a reduced risk (hazard rate ratio = 0.83; 95% confidence interval = 0.73, 0.93) for incident hypertension, after adjustment for race, sex, age, education, and family history of high blood pressure.

Blood Pressure Measurements

Blood pressure was measured at each examination on the right arm with a Hawksley random-zero sphygmomanometer (W.A. Baum Co, Copiague, NY) after a 5-minute seated rest. Three measurements were taken at 1-minute intervals, with systolic and diastolic pressures recorded at Phase I and Phase V Korotkoff sounds. The average of the second and third measurements was used for analysis. Before each examination, participants were asked to fast for at least 12 hours and not to smoke or engage in heavy physical activity for at least 2 hours prior to the examination.

Endpoint Definitions

Incident hypertension was defined as first occurrence at any follow-up examination of systolic blood pressure 140 mm Hg or higher or diastolic blood pressure 90 mm Hg or higher or of the person taking antihypertensive medication. The hypertension endpoint is based on blood pressure cutpoints used in the seventh report of the Joint National Committee on Detection, Evaluation, and Treatment of High Blood Pressure. In addition, standardized questionnaires were used to collect self-report of a medical diagnosis of hypertension.

Assessment of Physical Activity

At each of the 6 exams, leisure-time physical activity was assessed with the CARDIA Physical Activity History Questionnaire, an interviewer-administered self-report of frequency of participation in each of 13 categories of sports and exercise during the previous 12 months. The 13 categories included 8 vigorous-intensity activities (running or jogging; racquet sports; biking; swimming; exercise or dance class; job lifting, carrying, or digging; shoveling or lifting during leisure; and strenuous sports) and 5 moderate-intensity activities (nonstrenuous sports, walking and hiking, golfing and bowling, home exercises or calisthenics, and home maintenance or gardening). For each activity, interviewers asked participants the following questions to assess frequency of participation:

(1) Did you [do this activity] in the past 12 months for at least 1 hour total time per month?
(2) How many months did you do this activity?
(3) How many months did you do this activity for at least ‘X’ hours per week?

“X” varied from 2 through 5. An intensity score was assigned to each activity. The exercise score was computed by multiplying the sum of months of infrequent activity plus 3 times the months of frequent activity by intensity of the activity, and summing over all activities; the score was expressed in “exercise units” (EU). The “unit” in statistical models was defined as 300 EU (approximately 1 standard deviation). For reference, 300 EU roughly approximates the American College of Sports Medicine recommendations for the amount of exercise needed to support weight loss (5 sessions of 1260 kJ [300 kcal] of energy expenditure weekly). The test–retest reliability over 2 weeks of the CARDIA Physical Activity History Questionnaire and its agreement with a detailed, 4-week activity history was 0.77 to 0.84, which is comparable to that of other surveys.

Other Covariates

Age was determined by self-reported birthdate at the baseline examination and confirmed at the second examination. Some of the younger participants were still in school at baseline; therefore, educational status was modeled as the highest self-reported number of years of schooling completed at any of the exams to better capture the ultimate years of education attained. Baseline self-reported number of alcoholic beverages (beer, wine, and liquor) consumed per day in a typical week was used to calculate alcohol consumed (mL per day). Smoking status was modeled as a categorical variable based on self-report at baseline with 3 possible categories (current smoker, former smoker, and never smoker). Body weight with light clothing was measured at baseline to the nearest 0.5 pound with a Detecto balance beam scale, model 439 (Detecto, Webb City, Mo), and baseline height was measured without shoes to the nearest 0.5 cm with a vertically mounted centimeter ruler and metal carpenter’s square. Body mass index was calculated as weight in kilograms divided by height in meters squared (kg/m²). Waist circumference was measured midway between the umbilicus and the bottom of the ribcage to the nearest 0.5 cm. Fasting insulin was measured during the baseline examination by a modification of the immunoassay techniques of Herbert et al. Fasting insulin was log transformed because of skewed distribution.

Statistical Analyses

All statistical analyses were performed with SAS version 8.2 (SAS Institute Inc, Cary, NC). Means and standard deviations were computed for all descriptive characteristics and differences across race. Gender categories were assessed using the F test with 3 numerator degrees of freedom and a significance level of .05. Hazard rate ratios (RR) and 95% confidence intervals (CI) that predicted the first occurrence of incident hypertension were calculated with proportional hazards life table regression models. In these analyses, study participants lost to follow-up were censored at the last time point available. To account for changes in physical activity and to increase precision and validity, mean physical activity was computed by updating the measure of physical activity as the mean physical activity at all available prior exams. For example, through year 2, baseline physical activity was used; through year 5, physical activity was updated to the mean of baseline and year-2 measurements; through year 7, physical activity was updated to the mean of baseline, year-2, and year-5 measurements; and so on. In addition, change in physical activity was computed as the most recent measure of physical activity minus the average of all previous measures.

We developed 3 sets of models. The first set estimated the hazard rate ratio adjusted for study center and age, race, and gender (model A). A second set of models included additional variables that were observed to be significant predictors or were known confounders in the relationship of physical activity and hypertension (model B); these included education and family history of high blood pressure. Finally, model C added...
variables that were hypothesized to be on the causal pathway—baseline waist circumference and baseline fasting insulin. Effect modification by race and gender was assessed using multiplicative interaction terms that had a significance at baseline differed across race and gender was assessed using a causal pathway—baseline waist circumference variables that were hypothesized to be on the causal pathway. Mean physical activity appeared to go down over follow-up regardless of race or gender. An additional table that shows changes in physical activity over 15 years of follow-up stratified by the median of baseline physical activity is available as a supplement to the online version of this article. For each race and gender group, those who were below the median physical activity at baseline had a slight mean increase, whereas those who were above the median at baseline had a mean decrease. Figure 1 shows the number of cases of the dependent variable (incident hypertension over 15 years of follow-up) for each race and gender group; incidence rates were highest in Blacks and lowest in White women.

Hazard rate ratios and 95% CIs for the prediction of incident hypertension from average physical activity are shown in Table 3. An adjustment for study center, race, gender, and age (model A) gave a hazard rate ratio of 0.81 (95% CI = 0.72, 0.91). After adjustment for potential confounders was added, namely education and family history of high blood pressure (model B), a statistically significant reduction in risk of incident hypertension remained (RR for average physical activity = 0.83; 95% CI = 0.73, 0.93). Potential mediators were evaluated by the addition of baseline fasting insulin and waist circumference to the model (model C). There was attenuation of the relationship between average physical activity and incident hypertension in model C (RR = 0.85; 95% CI = 0.76, 0.96); the findings from model C suggest that fasting insulin and adiposity may be on the causal pathway that links physical activity and incident hypertension. We examined several other possible covariates, including 2 baseline behaviors that may be correlated with average physical activity (alcohol use and smoking status) and several other possible mediators (baseline body mass index, ln(triglycerides), and high-density lipid cholesterol); these variables were neither significant when added to model C, nor did they alter the magnitude or statistical significance of the average physical activity coefficient (data not shown).

Hazard rate ratios and 95% CIs for the prediction of incident hypertension from change in physical activity were also shown in Table 3. An adjustment for study center, race, gender, and age in the association of

### RESULTS

In general, demographic and other characteristics at baseline differed across race and gender groups (Table 1), including baseline blood pressure. Men had higher blood pressure than did women. Baseline physical activity level was highest in men, followed by White women, and then Black women. Race–gender differences in the distributions of several covariates are also given in Table 1. Table 2 shows mean physical activity and standard deviation at each examination in CARDIA over 15 years of follow-up. In general, mean physical activity appeared to go down over follow-up regardless of race or gender. An additional table that shows changes in physical activity over 15 years of follow-up stratified by the median of baseline physical activity is available as a supplement to the online version of this article. For each race and gender group, those who were below the median physical activity at baseline had a slight mean increase, whereas those who were above the median at baseline had a mean decrease. Figure 1 shows the number of cases of the dependent variable (incident hypertension over 15 years of follow-up) for each race and gender group; incidence rates were highest in Blacks and lowest in White women.

Hazard rate ratios and 95% CIs for the prediction of incident hypertension from average physical activity are shown in Table 3. An adjustment for study center, race, gender, and age (model A) gave a hazard rate ratio of 0.81 (95% CI = 0.72, 0.91). After adjustment for potential confounders was added, namely education and family history of high blood pressure (model B), a statistically significant reduction in risk of incident hypertension remained (RR for average physical activity = 0.83; 95% CI = 0.73, 0.93). Potential mediators were evaluated by the addition of baseline fasting insulin and waist circumference to the model (model C). There was attenuation of the relationship between average physical activity and incident hypertension in model C (RR = 0.85; 95% CI = 0.76, 0.96); the findings from model C suggest that fasting insulin and adiposity may be on the causal pathway that links physical activity and incident hypertension. We examined several other possible covariates, including 2 baseline behaviors that may be correlated with average physical activity (alcohol use and smoking status) and several other possible mediators (baseline body mass index, ln(triglycerides), and high-density lipid cholesterol); these variables were neither significant when added to model C, nor did they alter the magnitude or statistical significance of the average physical activity coefficient (data not shown).

Hazard rate ratios and 95% CIs for the prediction of incident hypertension from change in physical activity were also shown in Table 3. An adjustment for study center, race, gender, and age in the association of

### TABLE 1—Demographic and Other Characteristics of Adults Aged 18 to 30 Years Without Hypertension at Baseline: the CARDIA Study, United States, 1985–1986

<table>
<thead>
<tr>
<th>Variable</th>
<th>Black Mena (n = 815), mean ± SD or %</th>
<th>Black Womena (n = 1101), mean ± SD or %</th>
<th>White Mena (n = 967), mean ± SD or %</th>
<th>White Womena (n = 1110), mean ± SD or %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic pressure, mm Hg</td>
<td>114.8 ± 9.4</td>
<td>107.4 ± 9.9</td>
<td>114.7 ± 9.8</td>
<td>104.6 ± 8.8</td>
</tr>
<tr>
<td>Diastolic pressure, mm Hg</td>
<td>70.0 ± 9.7</td>
<td>66.7 ± 8.9</td>
<td>70.2 ± 8.8</td>
<td>66.0 ± 8.1</td>
</tr>
<tr>
<td>Exercise score, exercise unitsb</td>
<td>523.7 ± 343.6</td>
<td>279.2 ± 230.7</td>
<td>513.7 ± 299.2</td>
<td>405.4 ± 261.3</td>
</tr>
<tr>
<td>Age, y</td>
<td>24.4 ± 3.7</td>
<td>24.4 ± 3.9</td>
<td>25.4 ± 3.3</td>
<td>25.5 ± 3.4</td>
</tr>
<tr>
<td>Education, yc</td>
<td>13.5 ± 2.2</td>
<td>13.8 ± 2.1</td>
<td>15.5 ± 2.8</td>
<td>15.5 ± 2.5</td>
</tr>
<tr>
<td>Family history of high blood pressure, %</td>
<td>70.1</td>
<td>76.7</td>
<td>59.1</td>
<td>61.8</td>
</tr>
<tr>
<td>Current smoker, %</td>
<td>35.5</td>
<td>30.3</td>
<td>25.5</td>
<td>25.2</td>
</tr>
<tr>
<td>Alcohol, mL/day</td>
<td>17.4 ± 30.5</td>
<td>5.1 ± 12.5</td>
<td>18.2 ± 23.6</td>
<td>8.9 ± 16.1</td>
</tr>
<tr>
<td>Body mass index, kg/m²</td>
<td>24.5 ± 4.2</td>
<td>25.6 ± 6.2</td>
<td>24.2 ± 3.4</td>
<td>23.1 ± 4.3</td>
</tr>
<tr>
<td>Waist circumference, cm</td>
<td>80.5 ± 8.7</td>
<td>75.9 ± 12.4</td>
<td>82.5 ± 8.4</td>
<td>71.8 ± 9.2</td>
</tr>
<tr>
<td>Fasting insulin, µU/mL</td>
<td>10.7 ± 8.3</td>
<td>13.1 ± 8.9</td>
<td>9.0 ± 5.5</td>
<td>9.2 ± 6.8</td>
</tr>
</tbody>
</table>

Notes. CARDIA = Coronary Artery Risk Development in Young Adults; SD = standard deviation. Global differences exist (F test with 3 numerator degrees of freedom, P < .05) for all characteristics.

* Those with systolic pressure ≥140 mm Hg or diastolic pressure ≥90 mm Hg or who were taking antihypertensive medications at baseline were excluded. In addition, those who missed more than 2 follow-up exams were excluded from these analyses.

† Exercise score expressed in exercise units (frequency and intensity of exercise over the past year). For reference, 300 exercise units roughly approximates 5 sessions of 1260 kJ (300 kcal) of energy expenditure weekly.

### TABLE 2—Physical Activity (Mean ± SD) at Baseline and Follow-Up Over 15 years in Adults Aged 18 to 30 Years Without Hypertension at Baseline: the CARDIA Study, United States, 1985–1986

<table>
<thead>
<tr>
<th>Race and Gender</th>
<th>No.</th>
<th>Baselinea</th>
<th>Year 2</th>
<th>Year 5</th>
<th>Year 7</th>
<th>Year 10</th>
<th>Year 15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black men</td>
<td>815</td>
<td>523.7 ± 343.6</td>
<td>494.4 ± 343.1</td>
<td>481.9 ± 353.4</td>
<td>447.1 ± 329.5</td>
<td>438.7 ± 326.3</td>
<td>427.8 ± 330.9</td>
</tr>
<tr>
<td>Black women</td>
<td>1101</td>
<td>279.2 ± 231.2</td>
<td>247.7 ± 218.6</td>
<td>261.3 ± 229.1</td>
<td>221.9 ± 211.6</td>
<td>211.1 ± 204.7</td>
<td>238.6 ± 225.7</td>
</tr>
<tr>
<td>White men</td>
<td>967</td>
<td>513.7 ± 299.2</td>
<td>469.5 ± 285.0</td>
<td>459.9 ± 292.0</td>
<td>414.9 ± 268.6</td>
<td>415.3 ± 276.7</td>
<td>423.1 ± 279.8</td>
</tr>
<tr>
<td>White women</td>
<td>1110</td>
<td>405.4 ± 261.3</td>
<td>3523.0 ± 234.7</td>
<td>347.5 ± 255.5</td>
<td>304.1 ± 224.6</td>
<td>305.6 ± 235.4</td>
<td>328.8 ± 259.4</td>
</tr>
</tbody>
</table>

Notes. SD = standard deviation; CARDIA = Coronary Artery Risk Development in Young Adults. Those with systolic pressure ≥140 mm Hg or diastolic pressure ≥90 mm Hg or who were taking antihypertensive medications at baseline were excluded. In addition, those who missed 2 or more exams were excluded.

*aBaseline physical activity expressed in exercise units. Exercise score expressed in exercise units (frequency and intensity of exercise over the past year). For reference, 300 EU roughly approximates 5 sessions of 1260 kJ (300 kcal) of energy expenditure weekly.
change in physical activity and incident hypertension (model A) gave a hazard rate ratio of 0.89 (95% CI = 0.79, 0.99). The hazard rate ratio was unchanged after adjustment for potential confounders and mediators of the relationship.

There was little evidence for effect modification of the association of average physical activity and incident hypertension by race or gender. The race–gender-specific estimates in Table 3 were similar to those for the entire cohort, except that the association was attenuated in all groups except for the Black men and completely attenuated after adjustment for confounders in White women. We noted that CIs were widest among White women, perhaps because of the rarity of incident hypertension in this group. In further sensitivity analyses (data not shown), findings were similar if a high normal blood pressure cutpoint of 130 mm Hg systolic or 85 mm Hg diastolic was substituted for the cutpoint of 140 mm Hg systolic or 90 mm Hg diastolic used elsewhere in this article. We also tested for statistical interaction of physical activity and overweight status (BMI <25 kg/m² or ≥25 kg/m²) in association with incident hypertension and for statistical interaction or physical activity and baseline systolic blood pressure (<130 mm Hg or ≥130 mm Hg) in the association with incident hypertension. No statistical interaction was observed.

### DISCUSSION

After we adjusted for age, study center, education, and family history of hypertension, we observed a modest, statistically significant 17% reduction of risk of incident hypertension per 300-EU increment in average physical activity and an 11% reduction risk per 300-EU increase in physical activity among young adults in the CARDIA study. The association between average physical activity and incident hypertension was attenuated (15% reduction of risk) but remained marginally significant after adjustment for physiological variables that may mediate the association. This attenuation suggests that physical activity may be linked to incident hypertension in part through its influence on fasting insulin and waist circumference. The association between change in physical activity and incident hypertension was unchanged after confounders and mediators were added to the models. There was no significant race–gender interaction. The associations were consistent although not statistically significant across race–gender groups, with the exception of Black men.

We also observed changes in physical activity over 15 years of follow-up. For each race–gender group, those who were below the median for physical activity at baseline had a slight increase, whereas those who were above the median at baseline had a decrease (data shown in a table available as a supplement to the online version of this article); these findings are congruent to those reported by Andersen et al.25

Regular physical activity has been reported to lower blood pressure in adults with hypertension.3 A review article by Hagberg and Seals26 concluded that hypertensive adults who underwent aerobic exercise training as part of an intervention trial reduced their diastolic pressure from 97 mm Hg to 89 mm Hg and their systolic blood pressure from 154 mm Hg to 143 mm Hg. Similarly, a review by Fagard12 concluded that aerobic exercise training from 3 to 5 times per week for 30 to 60 minutes per session at moderate intensity lowered blood pressure by 3 mm Hg systolic and 2 mm Hg diastolic in normotensives and 7 mm Hg systolic and 6 mm Hg diastolic in hypertensives. Dengel et al. showed that exercise and weight loss can reduce blood pressure in hypertensive middle-aged men.9 These findings suggest that habitual exercise can reduce blood pressure in both hypertensive and normotensive middle-aged and older adults.

Physical activity has consistently been shown to reduce the risk of incident hypertension in adults in observational studies.2,3,9,15,27–33 It has previously been shown that regular physical activity reduced the odds of hypertension in normotensive middle-aged White men2,9,29,32 and in older women.33 In a longitudinal study, Pereira et al. concluded that leisure-time physical exercise...
TABLE 3—Multivariable Proportional Hazards Regression Results (RR) and 95% Confidence Intervals (CI) in an Examination of the Relationship of Mean Physical Activity (PA), Change in PA, and Incident Hypertension Over 15 Years of Follow-Up in Adults Aged 18 to 30 Years: the CARDIA Study, United States, 1985–1986 to 2000–2001

<table>
<thead>
<tr>
<th>Physical Activity Variable</th>
<th>Model A* RR (95% CI)</th>
<th>Model B# RR (95% CI)</th>
<th>Model Cc RR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All participants (N = 3993; n = 634)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average PA</td>
<td>0.81 (0.72, 0.91)</td>
<td>0.83 (0.73, 0.93)</td>
<td>0.85 (0.76, 0.96)</td>
</tr>
<tr>
<td>Change in PA</td>
<td>0.89 (0.79, 0.99)</td>
<td>0.89 (0.79, 1.00)</td>
<td>0.89 (0.80, 1.00)</td>
</tr>
<tr>
<td>Black men (N = 615; n = 204)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average PA</td>
<td>0.81 (0.67, 0.97)</td>
<td>0.80 (0.67, 0.95)</td>
<td>0.82 (0.68, 0.98)</td>
</tr>
<tr>
<td>Change in PA</td>
<td>0.90 (0.76, 1.07)</td>
<td>0.90 (0.76, 1.06)</td>
<td>0.91 (0.77, 1.07)</td>
</tr>
<tr>
<td>Black women (N = 1101; n = 231)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average PA</td>
<td>0.76 (0.58, 0.99)</td>
<td>0.80 (0.61, 1.05)</td>
<td>0.78 (0.60, 1.03)</td>
</tr>
<tr>
<td>Change in PA</td>
<td>0.89 (0.71, 1.07)</td>
<td>0.88 (0.70, 1.10)</td>
<td>0.86 (0.69, 1.08)</td>
</tr>
<tr>
<td>White men (N = 967; n = 133)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average PA</td>
<td>0.83 (0.66, 1.05)</td>
<td>0.84 (0.66, 1.06)</td>
<td>0.88 (0.70, 1.12)</td>
</tr>
<tr>
<td>Change in PA</td>
<td>0.80 (0.62, 1.04)</td>
<td>0.80 (0.63, 1.04)</td>
<td>0.83 (0.65, 1.07)</td>
</tr>
<tr>
<td>White women (N = 1110; n = 66)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average PA</td>
<td>0.89 (0.58, 1.35)</td>
<td>1.02 (0.68, 1.54)</td>
<td>1.16 (0.76, 1.75)</td>
</tr>
<tr>
<td>Change in PA</td>
<td>0.94 (0.63, 1.40)</td>
<td>0.97 (0.66, 1.42)</td>
<td>1.03 (0.70, 1.51)</td>
</tr>
</tbody>
</table>

Notes. N = number at risk; n = number of hypertensives over follow-up. Average PA is the average over follow-up. Change in PA is the most recent measure of PA minus the average of all previous measures. All other variables measured at baseline. Hazard rate ratio of incident hypertension is per 300 exercise units. Incident hypertension defined as the first occurrence of 140 mm Hg systolic blood pressure, 90 mm Hg diastolic blood pressure, or self-report of antihypertension medication use. Those with baseline hypertension or missing data at more than 2 exams were excluded. Model A adjusted for clinical center, age, race and sex; race–sex stratified models adjusted for clinical center and age. Model B adjusted for Model A variables plus highest reported educational attainment, and family history of high blood pressure ever reported. Model C adjusted for Model B variables plus baseline fasting insulin (ln transformed) and baseline waist circumference.

Strengths and Limitations

Few studies have looked at associations between physical activity and incident hypertension in young adults with comparable follow-up time. Previously, Dyer et al. observed an inverse but statistically insignificant association in all race–gender groups between baseline physical activity and incident high–normal blood pressure (systolic 130 mm Hg or diastolic 85 mm Hg) over 10 years of follow-up in the CARDIA cohort. The analyses presented here used the physical activity data from 4 or more exams to compute a mean physical activity level over the 15-year follow-up period, as well as changes in physical activity over time. Quantification of the relationship between physical activity and blood pressure presented some measurement challenges. For example, it is possible that the results presented here were influenced by the limitations of self-reported physical activity measures in general.
or more specific limitations of the CARDIA Physical Activity History Questionnaire. Self-reported physical activity data are subject to recall bias. Furthermore, the CARDIA Physical Activity History Questionnaire focused almost exclusively on leisure-time physical activity (there was 1 question about heavy lifting at work). Possibly, the measurement of multiple domains of physical activity (e.g., household chores, transportation, self-care, occupation) would better explain the hypothesized association of physical activity with incident hypertension. Domains of physical activity other than leisure time may be important, as suggested by the finding that mortality was not reduced for higher physical activity in women if only leisure activity was considered but was reduced if nonleisure physical activities were also considered.\textsuperscript{44}

Despite the weaknesses of self-reported physical activity data, the unique features of the CARDIA study offered many advantages. Specifically, the long follow-up period, the large cohort, the repeated examinations,\textsuperscript{41} the standardized questionnaire, and the population-based sample of relatively young Black and White men and women of the CARDIA study provided a unique opportunity to examine the combined impact of aging and physical inactivity on incident hypertension.

Conclusions

We observed a statistically significant inverse association of physical activity and incident hypertension in young adults. The association remained after adjustment for age, race, gender, and education, as well as for waist circumference and other physiological variables that may be mediators of the relationship. The results of this study are congruent with lifestyle modifications recommended by the Joint National Committee on Prevention, Protection, Evaluation, and Treatment of High Blood Pressure,\textsuperscript{20} which indicates that physical activity merits attention in the prevention of hypertension in Black and White men and women even when they are young adults. ■

About the Authors

Emily D. Parker, David R. Jacobs, and Pamela J. Schreiner are with the Division of Epidemiology and Community Health, School of Public Health, University of Minnesota, Minneapolis. Kathryn H. Schmitz is with the Center for Clinical Epidemiology and Biostatistics, University of Pennsylvania, Philadelphia. Donald H. Dengel is with the School of Kinesiology, University of Minnesota, Minneapolis. Requests for reprints should be sent to Dr David R. Jacobs Jr, Division of Epidemiology and Community Health, School of Public Health, University of Minnesota, 1300 South 2nd St, Suite 300, Minneapolis, MN 55454 (e-mail: jacobs@epi.umn.edu).

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Contributors

D.R. Jacobs and P.J. Schreiner supervised all aspects of the study. E.D. Parker, D.R. Jacobs, and K.H. Schmitz completed the analysis and interpretation of the data. E.D. Parker synthesized analysis and led the writing of the article. D.R. Jacobs provided statistical expertise. All authors helped to conceptualize ideas and review drafts of the article.

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Human Participant Information

This study was approved by the University of Minnesota’s institutional review board.

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