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Robin P. Shook

Duck-chul Lee

Xuemei Sui

*University of South Carolina - Columbia*, [msui@mailbox.sc.edu](mailto:msui@mailbox.sc.edu)

Vivek Prasad

Steven P. Hooker

*University of South Carolina - Columbia*

*See next page for additional authors*

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**Author(s)**

Robin P. Shook, Duck-chul Lee, Xuemei Sui, Vivek Prasad, Steven P. Hooker, Timothy S. Church, and Steven N. Blair

# Cardiorespiratory Fitness Reduces the Risk of Incident Hypertension Associated With a Parental History of Hypertension

Robin P. Shook, Duck-chul Lee, Xuemei Sui, Vivek Prasad, Steven P. Hooker, Timothy S. Church, Steven N. Blair

**Abstract**—Family history of hypertension increases the risk of an individual to develop hypertension, whereas moderate-to-high cardiorespiratory fitness has the opposite effect. However, the joint association of each on the development of hypertension is not well understood. We studied fitness and incident hypertension in 6278 participants who were given a preventative medical examination. Thirty-three percent reported a parent with hypertension, and there were 1545 cases of incident hypertension after a mean of 4.7 years. The presence of parental hypertension was associated with a 28% higher risk of developing hypertension after adjustments for age, sex, and examination year. After further adjustments for smoking, alcohol intake, resting systolic and diastolic blood pressures, hypercholesterolemia, body mass index, physical inactivity, and fitness, there was a 20% higher risk associated with parental hypertension. After adjusting for age, sex, and examination year, both moderate and high levels of fitness were associated with lower risk for developing hypertension by 26% and 42%, respectively. In the joint analysis, individuals with both a low level of fitness and a parent with hypertension exhibited a 70% higher risk for developing hypertension compared with high fit individuals with no parental history ( $P=0.004$ ). However, individuals with a high level of fitness and a parent with hypertension only experienced a 16% higher risk of developing hypertension compared with fit individuals with no parental history ( $P=0.03$ ). The significantly lower risk of developing hypertension when progressing from low- to high-fit groups among those with a parental history of hypertension has important clinical implications. (*Hypertension*. 2012;59:1220-1224.)

**Key Words:** exercise ■ fitness ■ blood pressure ■ hypertension ■ family history ■ risk factors

It is well established that regular physical activity and being moderately fit are associated with a reduced risk of developing hypertension.<sup>1–3</sup> Indeed, the National High Blood Pressure Education Program lists “engaging in moderate physical activity” as 1 of 6 effective strategies for the primary prevention of hypertension.<sup>4</sup> More than 40 years ago, Paffenbarger et al<sup>5</sup> reported parental hypertension to be the strongest sociofamilial influence on the development of hypertension in the College Alumni Health Study. Subsequent work has supported this, and it is estimated a parental history accounts for 35% to 65% of the variability in blood pressure among offspring,<sup>6–8</sup> with varying levels of risk based on which parent developed hypertension<sup>9,10</sup> and the age of that onset.<sup>9,10</sup>

Despite the protective benefits of high levels of cardiorespiratory fitness (CRF) and the elevated risk associated with a history of parental hypertension, the joint association of each on the development of hypertension is not well understood. Identifying modifiable risk factors such as CRF could help clinicians promote preventative strategies that may offset nonmodifiable risk factors, such as familial history.

The present study examined the independent and combined effects of fitness and parental history of hypertension in men and women on the development of hypertension.

## Methods

### Study Population

The Aerobics Center Longitudinal Study (ACLS) is an ongoing cohort study that investigates the relationship of CRF, physical activity, and other factors to chronic diseases.<sup>11</sup> Data were obtained from patients of the Cooper Clinic in Dallas, Tex. Many participants were sent by their employers for the examination, some were referred by their personal physicians, whereas others were self-referred. The present study consists of 6278 men and women aged 20 to 80 years who completed a baseline examination at the Cooper Clinic during 1988–2005. The sample was predominantly white, well educated, and from the middle and upper socioeconomic strata. At baseline, all of the participants included in the analysis were free of known cardiovascular disease, cancer, abnormal resting or exercise ECG, and diabetes mellitus and were able to achieve an exercise test to  $\geq 85\%$  of their age-predicted maximal heart rate ( $220 - \text{age}$ ). They also reported no diagnosis of hypertension by a physician and had resting blood pressure of  $<140/90$  mm Hg at baseline. The study

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From the Departments of Exercise Science (R.P.S., D.-c.L., X.S., V.P., S.N.B.) and Epidemiology and Biostatistics (S.N.B.), Arnold School of Public Health, University of South Carolina, Columbia, SC; School of Nutrition and Health Promotion (S.P.H.), Arizona State University, Phoenix, AZ; Preventive Medicine Laboratory (T.S.C.), Pennington Biomedical Research Center, Baton Rouge, LA.

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Correspondence to Robin P. Shook, Public Health Research Center, 921 Assembly St, Suite 212, Columbia, SC 29201. E-mail shookr@mailbox.sc.edu  
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protocol was approved annually by the institutional review board of the Cooper Institute.

### Baseline Examination

The baseline clinical examination was administered after receiving written informed consent from each participant for both the baseline examination and follow-up assessments. Baseline measures included resting blood pressure, fasting blood chemistry analyses, personal and family health history, anthropometry, and ECG. The baseline examination has been described previously in detail elsewhere.<sup>2,11,12</sup> Resting blood pressure was measured by trained technicians using auscultatory methods in the seated position and was recorded as the first and fifth Korotkoff sounds after  $\geq 5$  minutes of sitting quietly using mercury sphygmomanometers. Two readings separated by 1 minute were averaged. If the first 2 readings differed by  $> 5$  mmHg, additional readings were obtained and averaged. Serum samples were analyzed for glucose and total cholesterol using standardized automated bioassays. Diabetes mellitus was defined as fasting plasma glucose concentration of  $\geq 126$  mg/dL, a history of physician diagnosis, or insulin use. Hypercholesterolemia was defined as total cholesterol of  $\geq 240$  mg/dL or a history of physician diagnosis.<sup>13</sup> Height and weight were measured, and body mass index was calculated as weight in kilograms divided by height in meters squared. Information on parental history of hypertension, smoking habits (never, former, or current smoker), alcohol intake (drinks per week), and physical activity habits (physically inactive or not) were obtained from a standardized questionnaire. Consuming  $> 14$  drinks per week for men and 7 drinks per week for women was defined as heavy alcohol drinking. Physically inactive was defined as reporting no leisure-time physical activity in the 3 months before the examination. Participants were asked to select from a list of existing parental health problems.

CRF was quantified as the total time of a symptom-limited maximal treadmill exercise test, using a modified Balke protocol.<sup>2,14</sup> Total treadmill endurance time of the test on this protocol correlates highly with measured maximal oxygen uptake in both men ( $r=0.92$ )<sup>15</sup> and women ( $r=0.94$ ).<sup>16</sup> We have defined low, moderate, and high CRF exposures according to the lowest 20%, the next 40%, and the upper 40%, respectively, of the age- and sex-specific distributions of maximal exercise duration in the overall ACLS population. We use this approach because a widely accepted clinical categorization of CRF does not exist, and this cut point has been used as a standardized fitness classification method, which has shown low fitness to be an independent risk factor of morbidity and mortality.<sup>11,17</sup> Because unhealthy individuals who had a history of hypertension, diabetes mellitus, heart attack, stroke, or cancer or an abnormal ECG at baseline were excluded, the number of participants in this study classified as having a low fitness level was  $< 20\%$  compared with the entire ACLS cohort.

### Ascertainment of Hypertension

Hypertension was ascertained by the presence of resting blood pressure criteria of the National High Blood Pressure Education Program,<sup>18</sup> a self-report history of physician diagnosis or a measured resting systolic or diastolic blood pressure of  $\geq 140$  or  $\geq 90$  mmHg, respectively, at a follow-up clinic evaluation. Participants with hypertension at baseline by any of these criteria were excluded from the current study. This method of case ascertainment is similar to those used in other well-known epidemiological studies on hypertension.<sup>19–21</sup>

### Statistical Analysis

Descriptive statistics were calculated for each variable using  $\chi^2$  tests or  $t$  tests. The primary exposure variable was parental hypertension and CRF defined categorically as low, moderate, and high as described above. Follow-up time was computed as the difference between the date of the baseline examination and the date of first hypertension event or the last clinic visit through the end of 2005. Cox proportional hazards regression analysis was used to estimate hazard ratios (HRs) and 95% CIs of hypertension events according to

exposure categories. To test effect modification by sex on the associations between parental hypertension or CRF and incident hypertension, we compared risk estimates in the sex-stratified analyses and checked interaction terms in the Cox regressions. There were similar trends in developing hypertension between men and women, and no significant interactions were observed. Thus, we presented the results of pooled analyses. Inspection of empirical cumulative hazards plots (log–log [survival function] versus log [time] across number of health-risk factors) indicated that the proportional hazards assumption was justified. All of the statistical analyses were performed by SAS software (SAS Institute, Cary, NC), and all of the  $P$  values are 2 sided, with an  $\alpha$ -level of 0.05.

### Results

There were 1545 cases of incident hypertension among 6278 participants after a mean of 4.7 follow-up years, with 33% of the sample reporting a parent with hypertension. The baseline characteristics of the study population are presented in Table 1. Study participants were middle-aged ( $44.7 \pm 8.7$  years), mostly men (76.1%), slightly overweight (body mass index,  $25.2 \pm 3.3$  kg/m<sup>2</sup>), predominantly active (79.2%), and non-smokers (88.3%). Participants with parental hypertension were younger, had lower total cholesterol, had higher resting blood pressure, and had shorter maximal treadmill duration.

Table 2 shows the individual associations between parental hypertension or CRF and incident hypertension. This relationship was explored using 3 different models, after adjusting for age, sex, and examination year (model 1), further adjusting for smoking status, alcohol intake, resting blood pressure, presence of hypercholesterolemia, body mass index, and physical inactivity (model 2), and further adjusting for each of the other variables in the table (model 3). The presence of parental hypertension was associated with significantly higher risk of developing hypertension in each model, with 28% higher in the initial model and 20% in the full model. After adjusting for age, sex, and examination year, both moderate and high levels of CRF were associated with lower risk for developing hypertension by 26% and 42%, respectively. The risk reduction for moderate levels of CRF was not maintained after further adjustment for variables in models 2 and 3 ( $P=0.15$  and  $P=0.16$ , respectively). However, the high level of CRF remained significantly protective for the development of hypertension after adjustments for variables in both models 2 and 3 (HR, 0.75 [95% CI, 0.58–0.96] for each model).

The Figure displays the joint association among parental hypertension, CRF, and incident hypertension after adjustment for the same covariables in the independent association analyses. Individuals who were in the lowest fitness category and had a parent with hypertension exhibited a 70% higher risk for developing hypertension compared with individuals in the highest fitness category with no parental history of hypertension ( $P=0.0041$ ). However, individuals who had a parent with hypertension and a high level of CRF only experienced a 16% increased risk of developing hypertension compared with fit individuals with no parental history of hypertension ( $P=0.03$ ). In an additional analysis among only those individuals with parental history of hypertension, moderately and highly fit individuals had 21% (HR, 0.79 [95% CI, 0.54–1.15]) and 34% (HR, 0.66 [95% CI, 0.45–0.97])

**Table 1. Baseline Characteristics According to Sex and Parental Hypertension Category, Aerobics Center Longitudinal Study Database, 1988–2005**

| Characteristic                     | Sex             |                   |                     | <i>P</i> Value | Parental Hypertension |                |                |
|------------------------------------|-----------------|-------------------|---------------------|----------------|-----------------------|----------------|----------------|
|                                    | All<br>(n=6278) | Males<br>(n=4781) | Females<br>(n=1497) |                | Yes<br>(n=2084)       | No<br>(n=4194) | <i>P</i> Value |
| Female, %                          | 23.9            |                   |                     |                | 29.6                  | 21.0           | <0.0001        |
| Age, y                             | 44.7±8.7        | 44.7±8.6          | 44.5±9.0            | 0.3745         | 44.1±8.1              | 45.0±9.0       | 0.0001         |
| Body mass index, kg/m <sup>2</sup> | 25.2±3.3        | 26.0±2.9          | 22.8±3.3            | <0.0001        | 25.1±3.4              | 25.3±3.3       | 0.0886         |
| Total cholesterol, mg/dL           | 200.4±37.4      | 202.5±37.6        | 193.5±35.8          | <0.0001        | 198.6±37.0            | 201.2±37.6     | 0.0095         |
| Hypercholesterolemia, %            | 25.7            | 27.7              | 19.4                | <0.0001        | 26.1                  | 25.5           | 0.6283         |
| Fasting glucose, mg/dL             | 96.0±8.4        | 97.3±8.2          | 92.0±7.6            | <0.0001        | 95.6±8.4              | 96.2±8.4       | 0.0072         |
| Resting blood pressure, mm Hg      |                 |                   |                     |                |                       |                |                |
| Systolic blood pressure            | 115.1±10.0      | 116.9±9.0         | 109.4±10.9          | <0.0001        | 115.6±10.1            | 114.9±10.0     | 0.0066         |
| Diastolic blood pressure           | 76.9±7.1        | 78.0±6.5          | 73.7±7.7            | <0.0001        | 77.2±7.0              | 76.8±7.1       | 0.0622         |
| Maximal treadmill time, min        | 18.8±4.8        | 19.9±4.4          | 15.2±4.2            | <0.0001        | 18.4±4.8              | 18.9±4.8       | <0.0001        |
| Cardiorespiratory fitness, %       |                 |                   |                     | <0.0001        |                       |                | 0.3622         |
| Low                                | 4.3             | 4.5               | 3.7                 |                | 4.7                   | 4.1            |                |
| Moderate                           | 29.6            | 31.2              | 24.5                |                | 30.1                  | 29.4           |                |
| High                               | 66.1            | 64.3              | 71.9                |                | 65.2                  | 66.6           |                |
| Physically inactive, %*            | 20.8            | 21.2              | 19.6                | 0.2099         | 20.4                  | 21.0           | 0.6345         |
| Smoking status, %                  |                 |                   |                     | <0.0001        |                       |                | 0.1461         |
| Never                              | 64.4            | 62.7              | 69.8                |                | 65.8                  | 63.7           |                |
| Former                             | 23.9            | 23.8              | 24.5                |                | 23.5                  | 24.2           |                |
| Current                            | 11.6            | 13.5              | 5.7                 |                | 10.7                  | 12.1           |                |
| Heavy alcohol drinking, %†         | 11.1            | 9.2               | 17.2                | <0.0001        | 10.9                  | 11.2           | 0.7737         |

\*Data include participants reporting no leisure-time physical activity in the 3 mo before the examination.

†Data include consuming >14 drinks per wk for men and >7 drinks per wk for women, as defined by the National Institute on Alcohol Abuse and Alcoholism.

lower risks of developing hypertension, respectively, compared with low-fit individuals.

## Discussion

In this sample of middle-aged men and women, we found that both parental hypertension and CRF were independently associated with the development of hypertension. The primary finding from this study is that the risk for developing hypertension among individuals with a parental history of hypertension is lower for those who are fit compared with those who are not. Although the protective influence of CRF on the development of hypertension has been shown previously, to our knowledge this is the first examination of this joint association among individuals with a parental history of hypertension. Previous research has estimated the increase in risk of developing hypertension among those whose parents also had hypertension to be 1.3 to 2.4.<sup>9,10,22–24</sup> In our fully adjusted model, the risk for developing high blood pressure if their parent had hypertension was 34% lower among highly fit individuals compared with low-fit individuals. By identifying the role of modifiable risk factors such as CRF on the development of hypertension, clinicians may promote preventative strategies, such as regular physical activity, to offset nonmodifiable risk factors, such as family history.

Physical activity has been shown previously to lower blood pressure in normotensive and hypertensive adults,<sup>25–27</sup> and higher levels of CRF are associated with lower risk of developing hypertension.<sup>1–3</sup> Despite this association, CRF has rarely been examined in previous research on the risk of hypertension associated with parental hypertension. Although most studies on parental hypertension fail to adjust for physical activity levels,<sup>22–24,28,29</sup> those that do have relied on self-report measures,<sup>9</sup> which are subject to misclassification.<sup>9,30,31</sup> To our knowledge, this is the first study to include objectively assessed CRF on the risk of hypertension associated with parental hypertension.

Individuals in our cohort reporting a parent with hypertension had a 20% higher risk of developing hypertension themselves compared with those without a history of parental hypertension. This value is similar to or slightly lower than those reported elsewhere,<sup>9,10,22–24,28,29,32,33</sup> although the reporting methods of identifying parental hypertension, type of study design, and socioeconomic characteristics of the sample likely explain a portion of any difference. The predictive strength of family history on offspring hypertension varies with the type of family history that is present. In the Johns Hopkins Precursor Study, level of risk varied by parent (mother only, HR, 1.5; father only, HR, 1.8; both, HR, 2.4)

**Table 2. HRs of Incident Hypertension by Parental Hypertension and Cardiorespiratory Fitness**

| Category                   | No. at Risk | No. of Cases | Model 1, HR (95% CI)* | Model 2, HR (95% CI)† | Model 3, HR (95% CI)‡ |
|----------------------------|-------------|--------------|-----------------------|-----------------------|-----------------------|
| Parental hypertension      |             |              |                       |                       |                       |
| No                         | 4194        | 995          | 1.0 (ref)             | 1.0 (ref)             | 1.0 (ref)             |
| Yes                        | 2084        | 550          | 1.28 (1.15–1.42)      | 1.19 (1.08–1.33)      | 1.20 (1.08–1.33)      |
| Cardiorespiratory fitness§ |             |              |                       |                       |                       |
| Low                        | 268         | 77           | 1.0 (ref)             | 1.0 (ref)             | 1.0 (ref)             |
| Moderate                   | 1858        | 481          | 0.74 (0.58–0.94)      | 0.84 (0.66–1.07)      | 0.84 (0.66–1.07)      |
| High                       | 4152        | 987          | 0.58 (0.46–0.73)      | 0.75 (0.58–0.96)      | 0.75 (0.58–0.96)      |

HR indicates hazard ratio; ref, referent.

\*Data were adjusted for age (single year), sex, and examination year.

†Data were adjusted for variables in model 1 plus smoking status (never, former, current), alcohol intake (heavy drinking, yes or no), resting systolic and diastolic blood pressures, hypercholesterolemia (present or not), body mass index, and physical inactivity (yes or no).

‡Data were adjusted for variables in model 2 plus each of the other variables in the table.

§Participants were categorized into 3 groups based on age- and sex-specific quintiles of maximal treadmill time in the overall Aerobics Center Longitudinal Study population, low as the lowest 20%, moderate as the middle 40%, and high as the upper 40%.

and age of onset (1 parent, late onset, HR, 1.5; both parents, early onset, HR, 6.2).<sup>9</sup> Our study only reports if a parent has hypertension, resulting in the inability to categorize risk to the level reported elsewhere.<sup>8</sup> In addition, the ACLS population in this study is composed of those who are relatively fit and physically active. As we have shown, a high level of fitness reduces the risk of developing hypertension after adjusting for a family history of hypertension (HR, 0.75; Table 2), which may explain lower hypertension rates compared with other studies.

The significantly lower risk of developing hypertension in highly fit individuals compared with low-fit individuals with a parental history of hypertension is worth further discussion and has important clinical ramifications. Previous analysis on the ACLS population found walking an average of 130 minutes per week for men and 150 minutes per week for women was associated with a moderate level of fitness (representing the 21–60 percentile of the overall ACLS

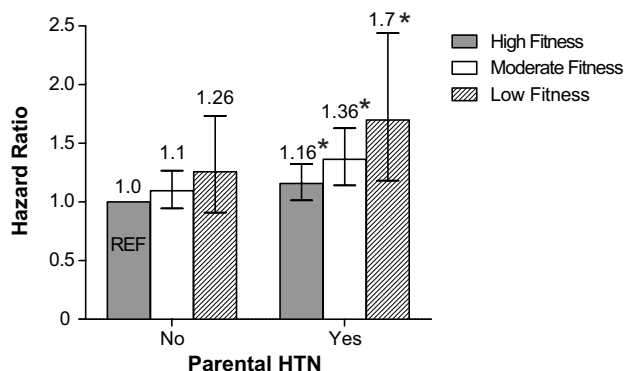
population).<sup>34</sup> This attainable level of physical activity closely resembles the 2008 Physical Activity Guidelines for Americans recommendation of 150 minutes per week<sup>35</sup> and the recommendations from the National High Blood Pressure Education Program for the primary prevention of hypertension.<sup>4</sup>

Strengths of the study include the valid and diverse measurements of exposure and outcome variables. CRF and body mass index were objectively measured during the medical examinations at baseline. In many previous studies, the effect of family history on incident hypertension has been determined without inclusion of physical activity or CRF in the analytic models or with self-reported physical activity that has limitations not found with objectively measured CRF. This study also benefits from a large sample size with high internal validity and an extended follow-up period.

The current study has limitations that deserve mention. The majority of participants were well-educated white men, of middle to upper class socioeconomic status, relatively fit, and physically active, which limits the generalizability of the findings. Family history of hypertension was assessed through self-report, which may be subject to recall bias. We only measured baseline levels of CRF and family history, and these may have changed during follow-up. However, the mean age of the sample makes a change in family history highly unlikely, because most of the participant's parents would have been at an age where chronic diseases were already present and diagnosed.

## Perspectives

The present study demonstrates that high levels of CRF are associated with a lower risk of developing hypertension among a large cohort of men and women with a parental history of hypertension. Individuals in our sample population who had a parent with hypertension yet were high fit were at a 34% lower risk of becoming hypertensive themselves



**Figure.** Hazard ratios of incident hypertension (HTN) associated with parental hypertension and cardiorespiratory fitness. Adjusted for age, sex, examination year, smoking status (never, past, current), alcohol intake (heavy drinking, yes or no), resting systolic and diastolic blood pressures, hypercholesterolemia (present or not), body mass index, and physical inactivity (yes or no). \* $P < 0.03$ .



compared with low-fit individuals with the same parental history. Our findings support current recommendations to engage in moderate levels of physical activity to prevent the development of hypertension, particularly among individuals at an elevated risk for the disease because of parental history of hypertension.

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