Healthy Lifestyle Through Young Adulthood and the Presence of Low Cardiovascular Disease Risk Profile in Middle Age

The Coronary Artery Risk Development in (Young) Adults (CARDIA) Study

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Background—A low cardiovascular disease risk profile (untreated cholesterol <200 mg/dL, untreated blood pressure <120/<80 mm Hg, never smoking, and no history of diabetes mellitus or myocardial infarction) in middle age is associated with markedly better health outcomes in older age, but few middle-aged adults have this low risk profile. We examined whether adopting a healthy lifestyle throughout young adulthood is associated with the presence of the low cardiovascular disease risk profile in middle age.

Methods and Results—The Coronary Artery Risk Development in (Young) Adults (CARDIA) study sample consisted of 3154 black and white participants 18 to 30 years of age at year 0 (1985–1986) who attended the year 0, 7, and 20 examinations. Healthy lifestyle factors defined at years 0, 7, and 20 included average body mass index <25 kg/m², no or moderate alcohol intake, higher healthy diet score, higher physical activity score, and never smoking. Mean age (25 years) and percentage of women (56%) were comparable across groups defined by number of healthy lifestyle factors. The age-, sex-, and race-adjusted prevalences of low cardiovascular disease risk profile at year 20 were 3.0%, 14.6%, 29.5%, 39.2%, and 60.7% for people with 0 or 1, 2, 3, 4, and 5 healthy lifestyle factors, respectively (P for trend <0.0001). Similar graded relationships were observed for each sex-race group (all P for trend <0.0001).

Conclusions—Maintaining a healthy lifestyle throughout young adulthood is strongly associated with a low cardiovascular disease risk profile in middle age. Public health and individual efforts are needed to improve the adoption and maintenance of healthy lifestyles in young adults. (Circulation. 2012;125:996-1004.)

Key Words: epidemiology ■ follow-up studies ■ prevention ■ risk factors

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he concept of a low cardiovascular disease (CVD) risk profile, encompassing optimal levels of all established, modifiable CVD risk factors, was proposed by Stamler et al1 in the late 1990s. Recently, there has been significant interest in the potential power of the low risk profile, if maintained into middle age, for substantially reducing the burden of CVD in the population. Research has shown that individuals with the low risk profile in middle age have dramatically lower total, cardiovascular, and noncardiovascular mortality rates; greater longevity; and substantially lower rates and remaining lifetime risks for CVD events compared with individuals without the profile.1–4 In addition, a low risk profile in middle age has been associated with a higher quality of life and lower Medicare charges in older age.5,6 Capewell and colleagues7 estimated that if all American adults had achieved the low risk profile by 2010, there would have been 95% fewer coronary heart disease deaths than expected in 2010. Based on the strength of all of these data, the low risk profile serves as the foundation for the American Heart Association’s 2020 Strategic Impact Goal8 and its focus on “ideal cardiovascular health.”

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However, the prevalence of the low risk profile in general is remarkably low. Using National Health and Nutrition Examination Survey (NHANES) 1999 to 2004 data, Ford et al9 estimated that the prevalence of a low risk profile (the same criteria stated above with an addition of body mass index [BMI] <25 kg/m²) in the United States was only 7.5%
overall among individuals 25 to 74 years of age and declined with age. It is unclear whether a low risk profile can be achieved in middle age by adopting healthy lifestyles. Longitudinal data from the Coronary Artery Risk Development in (Young) Adults (CARDIA) Study\(^1\) provide an important opportunity to assess whether adopting and maintaining a healthy lifestyle from young adulthood to middle age can help achieve a low CVD risk profile in middle age.

**Methods**

The CARDIA Study is a multicenter longitudinal study sponsored by the National Heart, Lung, and Blood Institute of the National Institutes of Health. The initial cohort consisted of 5115 black and white men and women 18 to 30 years of age who were free of CVD and were recruited in 1985 to 1986 (year 0 [Y0]) from 4 urban centers: Birmingham, AL; Chicago, IL; Minneapolis, MN; and Oakland, CA. The cohort was roughly balanced within each center by sex, race, age \(\leq 24\) or \(25\) to \(30\) years, and education (high school education or less or more than high school).

**Sample**

A detailed description of the study design has been published previously.\(^1\) Seven follow-up examinations have occurred at years 2, 5 (Y5), 7 (Y7), 10 (Y10), 15, 20 (Y20), and 25. Analyses for this study were based on a sample consisting of 3154 participants (1420 black, 1734 white; 1392 men, 1762 women) who attended the Y0, Y7, and Y20 examinations at which dietary intake was assessed. Women who were pregnant at the time of the Y0, Y7, or Y20 examination were excluded from these analyses. From the sample of 3154 participants who were included in the primary analysis, 818 were missing data on variables used in either the healthy lifestyle or the low risk profile definition. Specifically, 33, 114, and 372 participants were missing data on healthy lifestyle variables measured at Y0, Y7, and Y20, respectively; mainly diet data were missing. Another 117 participants had extreme reported caloric intake at Y0, Y7, or Y20 (>8000 or <800 kcal for men and >6000 or <600 kcal for women); their nutrient values were recoded as missing. Finally, of the remaining 182 who were missing data on low risk variables measured at Y20, 20 were missing cholesterol or blood pressure data, and 162 were missing glucose; glucose values were recoded as missing for participants who did not fast at least 8 hours. This left 2336 participants with complete data for all of the variables used to define low risk profile, healthy lifestyle factors (HLFs), and covariates.

**Data Collection**

All measurements were obtained by trained and certified technicians. Participants were asked to fast for 12 hours and to refrain from smoking and heavy physical activity for 2 hours before each examination. At Y0 and Y7, after a 5-minute rest period in a quiet room, a random-zero sphygmomanometer was used on each participant’s right arm to take 3 systolic and fifth-phase diastolic blood pressure measurements at 1-minute intervals. The average of the second and third blood pressure measurements was used in the analysis. At Y20, the Omron model HEM907XL (Omron Healthcare, Inc) was used to measure blood pressure. A calibration study was conducted \(n=800\) to convert Y20 values to their Y0 equivalents. Total cholesterol and high-density lipoprotein cholesterol were measured enzymatically by the Northwest Lipid Laboratories.\(^11,12\) The Friedewald equation was used to calculate low-density lipoprotein cholesterol.\(^13\) Fasting glucose was measured by Linco Research, Inc with the hexokinase ultraviolet method. Height and weight were measured with the participants wearing light clothing and no shoes. BMI was calculated as weight (kg) divided by the square of height \(\text{m}^2\). Sex, race, and years of education were self-reported. Alcohol intake (ml/d) was computed from the self-reported beer, wine, and liquor consumed per week.\(^14\) Smoking was self-reported on a tobacco use questionnaire previously validated by a study using serum cotinine levels.\(^15\) The physical activity score was derived from the CARDIA Physical Activity History previously validated by Jacobs et al.\(^16\) Dietary intake was assessed from the CARDIA dietary history, an interviewer-administered, quantitative food frequency questionnaire.\(^17\) Nutrient data, which included calcium, potassium, fiber, and saturated fat, were calculated from the University of Minnesota Nutrition Coordinating Center food composition database (version 10 for Y0, version 20 for Y7, and version 36 for Y20). Reliability and validity studies were previously performed on the questionnaire.\(^18\) Medication use was self-reported and recorded at Y0 and Y7; at Y20, participants were asked to bring their medications for verification. Participants provided written informed consent at each examination, and the data collection and cohort follow-up protocols have been approved by the Institutional Review Board of each field center and the Coordinating Center.

**Statistical Analysis**

The primary analysis examined the relationship between the number of HLFs defined on the basis of the average values from Y0, Y7, and Y20 and the prevalence of low CVD risk profiles at Y20. This low CVD risk profile at Y20 (henceforth referred to as the low risk profile) is defined as the absence of preexisting CVD and the simultaneous presence of untreated total cholesterol <200 mg/dL, untreated blood pressure <120/<80 mm Hg, no diabetes mellitus, and never smoking. We selected 5 HLFs on the basis of the data from Y0, Y7, and Y20: average BMI <25 kg/m\(^2\); average alcohol intake from 0 to 15 g/d for women and 0 to 30 g/d for men; within the highest 40% on a dietary score based on a mean intake of potassium, calcium, and fiber and lower intake of saturated fat (see below); within the highest 40% of the sex-specific distribution of average physical activity score (Y0, Y7, and Y20 examinations); and never smoking. These factors were selected to coincide with the healthy lifestyle pattern described by Stamper et al,\(^19\) which has been associated with lower CVD event rates and diabetes incidence in multiple cohorts.\(^20–22\) For the physical activity score, described in detail elsewhere,\(^23\) the highest 40% cut points were 480.0 and 307.3 exercise units for men and women, respectively. Roughly 300 exercise units approximates the recommendation by the American College of Sports Medicine\(^24\) for the amount of exercise needed to support weight loss (ie, energy expenditure equal to 1260 kJ [300 kcal] per session at 5 sessions per week).\(^23\) The dietary score was designed to be consistent with the Dietary Approaches to Stop Hypertension (DASH) eating pattern.\(^25\) The dietary scores were computed separately for each sex as follows. The average intakes from both food sources only of potassium (mg), calcium (mg), fiber (g), and saturated fat (g) from the Y0, Y7, and Y20 examinations were calculated for each participant. A quintile score (low=1 to high=5) for each mean intake of potassium, calcium, and fiber was assigned to each participant, and a quintile score (high=1 to low=5) was assigned for saturated fat intake. The 4 quintile scores were summed to create a total score ranging from 4 to 20. The highest 40% on this total score was defined as a healthy diet. For sensitivity analyses, a score based on the highest sex-specific 40% of the Alternate Healthy Eating Index (AHEI), proposed by McCulough and Willett,\(^26\) was also computed. The AHEI consists of 9 components representing intakes of vegetables, fruit, fish and poultry, nonmeat protein (eg, nuts and soy products), and whole grains; intake ratio of polyunsaturated to saturated fats; low trans fat intake; moderate alcohol consumption; and a long-term multivitamin component. The 2 last components (ie, alcohol consumption and multivitamin component) were not included in the score for the present study because our HLF score includes an alcohol component and data on long-term vitamin usage were not available at all 3 visits. Participants were stratified a priori into groups based on their total number of HLFs \((0–1, 2, 3, 4, \text{or} 5)\) from young adulthood to middle age.

The primary data analysis was based on the sample of 3154 participants who attended all 3 examinations at Y0, Y7 and Y20. The
Table 1. Baseline Characteristics (Mean or Percent) by Number of Healthy Lifestyle Factors, Year 0 to 20, Among CARDIA Participants (n=3154)

<table>
<thead>
<tr>
<th>Variable</th>
<th>0–1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>P for Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>n (%)</td>
<td>485</td>
<td>956</td>
<td>959</td>
<td>566</td>
<td>189</td>
<td></td>
</tr>
<tr>
<td>Age, y</td>
<td>25.4</td>
<td>25.5</td>
<td>24.9</td>
<td>25.0</td>
<td>25.1</td>
<td>0.006</td>
</tr>
<tr>
<td>Women, %</td>
<td>59.6</td>
<td>55.0</td>
<td>54.0</td>
<td>54.6</td>
<td>63.0</td>
<td>0.85</td>
</tr>
<tr>
<td>Black, %</td>
<td>59.4</td>
<td>53.4</td>
<td>42.2</td>
<td>32.5</td>
<td>16.9</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Education, y</td>
<td>14.4</td>
<td>15.3</td>
<td>15.8</td>
<td>16.3</td>
<td>17.2</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>SBP, mm Hg</td>
<td>111.7</td>
<td>110.6</td>
<td>109.9</td>
<td>109.6</td>
<td>108.0</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>DBP, mm Hg</td>
<td>68.5</td>
<td>69.1</td>
<td>68.5</td>
<td>68.3</td>
<td>68.3</td>
<td>0.33</td>
</tr>
<tr>
<td>BP medication, %</td>
<td>1.4</td>
<td>1.2</td>
<td>0.4</td>
<td>0.2</td>
<td>0</td>
<td>0.003</td>
</tr>
<tr>
<td>LDL-C, mg/dL</td>
<td>112.6</td>
<td>113.0</td>
<td>108.0</td>
<td>107.6</td>
<td>99.6</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>HDL-C, mg/dL</td>
<td>52.0</td>
<td>52.1</td>
<td>54.0</td>
<td>55.3</td>
<td>54.0</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Fasting glucose, mg/dL</td>
<td>83.0</td>
<td>82.7</td>
<td>81.9</td>
<td>81.5</td>
<td>82.4</td>
<td>0.04</td>
</tr>
<tr>
<td>Current smoker at Y0, %</td>
<td>68.3</td>
<td>30.1</td>
<td>16.1</td>
<td>8.3</td>
<td>0</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Low risk at Y0, %</td>
<td>16.5</td>
<td>36.7</td>
<td>52.5</td>
<td>55.5</td>
<td>69.3</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

CARDIA indicates Coronary Artery Risk Development in (Young) Adults; HLFs, healthy lifestyle factors; SBP, systolic blood pressure; DBP, diastolic blood pressure; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; and Y0, year 0.

*Sums to 3155 because of rounding.
†The overall unadjusted prevalence rate of low risk at baseline is 43.7%.

Results

Baseline (Y0) characteristics of the 3154 included participants stratified by the number of HLFs are presented in Table 1. The baseline average ages were slightly younger with greater numbers of HLFs, and the percentages of women were similar across HLF groups. The percentage of black participants was lower and the average level of education was higher among those with greater numbers of HLFs. Overall mean levels of systolic blood pressure, diastolic blood pressure, low-density lipoprotein cholesterol, fasting glucose, and high-density lipoprotein cholesterol were generally favorable for all 5 groups at baseline, when the participants were on average 25 years old. However, despite the overall favorable levels, all risk factors except diastolic blood pressure were associated with the number of HLFs, and the trends were in the expected direction. At baseline, 1379 participants (43.7%) had the low risk profile. For the majority of participants not classified as low risk at baseline, the main reason was smoking, although elevated blood pressure or cholesterol also contributed (data not shown).

At Y20, 774 participants (24.5%) had the low risk profile (Table 2). The age-, sex-, and race-adjusted prevalence rates of the low risk profile stratified by the number of HLFs, as defined by the average Y0, Y7, and Y20 values, are shown in Figure 1A. The prevalence of the low risk profile in middle age was significantly and substantially higher with increasing numbers of HLFs during the period from young adulthood to middle age. The prevalence rates were 3.0%, 14.6%, 29.5%, 39.2%, and 60.7% for people with 0 to 1, 2, 3, 4, and 5 HLFs, respectively. From these prevalence rates, the attributable risk for not having a low risk profile at Y20 that could be explained by not having all 5 HLFs was 48%. Compared with people who only have 0 to 1 HLF, the age-, sex-, and race-adjusted odds ratios for having a low risk profile at Y20 were 8.1, 20.5, 31.4, and 74.8 for people with 2, 3, 4, and 5 HLFs, respectively (Table 2). Because never smoking was considered an HLF and a low risk factor, the prevalence rates of low risk profile were estimated among never smokers, and the results were consistent (Table 2). Similar results were also obtained for the sample of 2336 young adults who had complete data (Figure 1B); again, the relationship was graded and highly significant (P for trend <0.0001). When we used the HLFs based on only the Y0 and Y7 average, the age-, sex-, and race-adjusted prevalence rates of low risk profile at Y20 were still strongly graded: 2.6%, 13.5%, 26.9%, 36.8%, and 50.1% for the group with 0 to 1, 2, 3, 4, and 5 HLFs, respectively (data not shown). Figure 2 displays the age-adjusted prevalence of the low risk profile at Y20 according to the number of HLFs stratified by sex and race. For all 4 sex and race groups, the prevalence rate was higher as the number of the HLFs increased (P for trend <0.0001 for all sex and race groups).

Table 3 shows the prevalence of the low risk profile for people who had at least 4 HLFs at various combinations of...
the Y0, Y7, and Y20 examinations. The age-, sex-, and race-adjusted prevalence ranged from 53.8% for those who had 4 or 5 HLFs at all 3 time points to 13.6% for those who did not have ≥4 HLFs at all 3 time points. Among those who adopted ≥4 HLFs at only 1 examination, the prevalence of a low risk profile was highest for those who adopted ≥4 HLFs at Y20. Similarly, among those who adopted ≥4 HLFs at 2 examinations, the prevalence of a low risk profile was highest for those who adopted ≥4 HLFs at the Y7 and Y20 examinations.

The Y20 prevalence of the low risk profile by individual HLFs over 20 years was analyzed after adjustment for age, sex, and race (Figure 3). The prevalence of the low risk profile was significantly higher for those with an average BMI <25 kg/m² than for those with an average BMI ≥25 kg/m² (P<0.0001). The low risk profile was significantly more prevalent among never smokers than among ever smokers (P<0.001). Low risk prevalence was significantly higher in those who had no or moderate alcohol intake on average compared with higher alcohol intake (P<0.001). Higher average levels of physical activity were associated with significantly higher prevalence of the low risk profile compared with lower levels of physical activity (P<0.01). Similar results were found for a healthier diet based on the original diet score (28.3% for a healthier diet versus 22.4% for a less healthy one; P<0.01) and the diet score based on the AHEI (27.8% for a healthier diet versus 22.3% for a less healthy diet; P<0.01; data not shown).

When “not currently smoking” (ie, not smoking at least 5 cigarettes per week almost every week in the last 3 months before the examination) replaced “never smoking” in the definitions of the low risk profile and the HLF, similar results were observed (Figure 4).

In addition, it is unclear whether the prospective association between HLFs and the low risk profile is also seen

![Figure 1](http://example.com/image1.png)

**Figure 1.** Age-, sex-, and race-adjusted prevalence of low risk profile at year 20 (Y20) by healthy lifestyle factors (HLFs) during year 0 (Y0) to Y20 among Coronary Artery Risk Development in (Young) Adults (CARDIA) Study participants. The graph in A is based on multiple imputation; the graph in B is based on complete data. P for trend was computed with logistic regression.

<table>
<thead>
<tr>
<th>HLFs, n*</th>
<th>0–1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>P for Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total never smokers through Y20, n§</td>
<td>558</td>
<td>729</td>
<td>492</td>
<td>189</td>
<td>0.0001</td>
<td></td>
</tr>
<tr>
<td>Low risk at Y20 among never smokers, %</td>
<td>25.1</td>
<td>39.2</td>
<td>46.1</td>
<td>64.0</td>
<td>&lt;0.0001</td>
<td></td>
</tr>
<tr>
<td>Odds ratio‡ (95% CI) for low risk at Y20 among never smokers</td>
<td>1.8 (1.4–2.4)</td>
<td>2.4 (1.8–3.2)</td>
<td>4.3 (2.9–6.3)</td>
<td>0.0001</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CARDIA indicates Coronary Artery Risk Development in (Young) Adults; HLFs, healthy lifestyle factors; Y20, year 20; and CI, confidence interval.

*HLFs are based on the average of year 0, 7, and 20 data.
†Sums to 3155 because of rounding.
‡Adjusted for age, sex, and race.
§Never smokers have at most 4 HLFs.
among people with family history of myocardial infarction. In CARDIA, we collected data on whether each parent had a history of myocardial infarction at Y0, Y5, and Y10. Among the 1220 participants with a positive parental history of myocardial infarction, the age-, race-, and sex-adjusted prevalences of the low risk profile were 2.6%, 11.5%, 25.7%, 31.9%, and 53.8% in the 0 to 1, 2, 3, 4, and 5 HLF groups, respectively.

In sensitivity analyses substituting the AHEI-based diet score, the prevalence of the low risk profile over the 5 HLF groups was still graded (Table I in the online-only Data Supplement) for all participants and when stratified by the 4 sex and race groups. However, the prevalence of the low risk profile was slightly lower in the group with 5 HLFs compared with the analysis based on the original diet score.

**Discussion**

Results of this study demonstrate a strong, graded relationship between the maintenance of healthy lifestyles from young adulthood to middle age and the presence of the low CVD risk profile in middle age. Three-fourths of white and black women and more than half of black and white men who adopted and maintained a healthy lifestyle with all 5 HLFs had a lower CVD risk profile after 20 years of follow-up, when the average age was 45 years. Our results also indicate that for each sex and race group, for the entire cohort, and in all sensitivity analyses, people with a higher number of HLFs have a significantly higher prevalence of the low CVD risk profile and vice versa. Moreover, among participants with a parental history of myocardial infarction, the graded relationship between a higher number of HLFs and the presence of low CVD risk profile also was consistent. These findings, which have significant public health implications, suggest that the low CVD risk profile in middle age can be achieved by adopting and maintaining a healthy lifestyle pattern early in adulthood.

Benefits of having the low CVD risk profile in middle age were first demonstrated by Stamler et al1 using 22-year follow-up data of the Chicago Heart Association Detection Project in Industry (CHA) and 16-year follow-up data of the Multiple Risk Factor Intervention Trial (MRFIT) Screenees Study. In both cohorts, mortality rates from coronary heart disease, CVD, and all causes in people with the low CVD risk profile were substantially lower than in others. Daviglus et al2 analyzed Medicare data and reported that middle-aged participants with the low CVD risk profile in the CHA study had much lower rates of various chronic diseases at older ages. Morbidity rates decreased as the number of low CVD risk factors increased. More recently, Lloyd-Jones et al4 used Framingham Heart Study data to show that the remaining lifetime risk of CVD was substantially lower for those with

Table 3. Age-, Race-, and Sex-Adjusted Prevalence of Low Risk Status at Year 20 by Presence or Absence of ≥4 Healthy Lifestyle Factors at Years 0, 7, and 20 (Using Imputed Data)

<table>
<thead>
<tr>
<th>Year 0</th>
<th>Year 7</th>
<th>Year 20</th>
<th>n*</th>
<th>Prevalence of Low Risk at Year 20 Requiring ≥4 HLFs, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>−</td>
<td>−</td>
<td>−</td>
<td>1648</td>
<td>13.6</td>
</tr>
<tr>
<td>+</td>
<td>−</td>
<td>−</td>
<td>471</td>
<td>23.9</td>
</tr>
<tr>
<td>−</td>
<td>+</td>
<td>−</td>
<td>174</td>
<td>29.8</td>
</tr>
<tr>
<td>−</td>
<td>−</td>
<td>+</td>
<td>105</td>
<td>37.5</td>
</tr>
<tr>
<td>+</td>
<td>+</td>
<td>−</td>
<td>284</td>
<td>37.7</td>
</tr>
<tr>
<td>+</td>
<td>−</td>
<td>+</td>
<td>103</td>
<td>39.0</td>
</tr>
<tr>
<td>−</td>
<td>+</td>
<td>+</td>
<td>86</td>
<td>52.2</td>
</tr>
<tr>
<td>+</td>
<td>+</td>
<td>+</td>
<td>285</td>
<td>53.8</td>
</tr>
</tbody>
</table>

* Indicates presence of ≥4 HLFs at the examination; −, absence of ≥4 HLFs at the examination.

*Sums to 3156, due to rounding.
the low CVD risk profile at 50 years of age than for people with ≥2 CVD risk factors. Furthermore, Capewell et al estimated that if all US adults had a low risk profile between 2000 and 2010, 372 000 fewer coronary heart disease deaths (95%) would have occurred in 2010. Benefits of the low CVD risk profile are not limited to only morbidity and mortality. Daviglus et al showed in the CHA study that a low CVD risk profile in middle age was associated with significantly higher health-related quality of life at older ages and significantly lower Medicare charges, both average annual charges and those in the last year of life.

Unfortunately, the prevalence of the low CVD risk profile is very low in the US population. In the CHA and MRFIT Screenes studies, baseline prevalence rates of the low risk profile range from 5% to 8%. In the recent report by Ford et al using National NHANES data, the prevalence in the US population was only 7.5%. However, as in our study, Ford et al noted that the prevalence is higher in younger age groups and declines dramatically with age. It has been unclear from these cross-sectional data whether the low risk profile can be achieved or maintained by adopting a healthy lifestyle.

In this study, 5 HLFs (never smoking, habitual moderate to vigorous physical activity, BMI < 25 kg/m², modest or no alcohol drinking, and a healthy diet) were selected to address this question. The selection of these lifestyle factors was based on the study by Stampfer et al, which

Figure 3. Age-, sex-, and race-adjusted prevalence of low risk profile at year 20 (Y20) by individual healthy lifestyle factors (HLF) among Coronary Artery Risk Development in (Young) Adults (CARDIA) Study Participants. P value was computed with logistic regression. BMI indicates body mass index.

Figure 4. Age-, sex-, and race-adjusted prevalence of low risk profile at year 20 (Y20) by healthy lifestyle factors (HLFs) during year 0 (Y0) to Y20 among Coronary Artery Risk Development in (Young) Adults (CARDIA) Study participants. In the low risk profile, “not a current smoker” replaces “never smoker.” The graph in A is based on multiple imputation; the graph in B is based on complete data. P for trend was computed with logistic regression.
clearly demonstrated that nurses with similar HLFs had a much lower risk of coronary heart disease. In addition, Vita et al. demonstrated that people with low risk profile, defined as normal BMI, no cigarette smoking, and vigorous exercise, had a much lower risk for disability than others. The justification for inclusion of each of these is important. Obesity has been associated with high blood pressure and high serum cholesterol and is the major risk factor for metabolic syndrome and type 2 diabetes mellitus. Cigarette smoking has been established as the most important risk factor for lung cancer and is one of the major risk factors for coronary heart disease. Excessive alcohol consumption has been associated with hypertension, breast cancer, and liver disease and mortality. The American Cancer Society and the AHA recommend no or moderate alcohol consumption. Unfortunately, in CARDIA, because of limitations of dietary data, we cannot directly define a healthy diet that is the same as the diet suggested by Stampfer et al or as the DASH diet. Instead, we used higher intake of potassium, calcium, and fiber and lower intake of saturated fat to define a healthy diet that is consistent with the DASH eating pattern. For example, high calcium intake reflects higher intake of dairy products; higher potassium and fiber intake reflects higher fruit, vegetable, and whole grain intake; and lower saturated fat intake reflects lower intake of red meat and butter. Habitual exercise has been shown to prevent CVD risk factors and CVD morbidity and mortality. In this study, pursuit of each of these HLF individually through young adulthood was significantly associated with the prevalence of low risk profile during middle age. We also performed a sensitivity analysis based on AHEI. The results are similar.

Across the 4 race and sex groups, the prevalence of low risk profile in middle age in the group with all 5 HLFs was much higher than the prevalence in the 0 to 1 HLF group. Although a very high percentage of participants in the group with 5 HLFs attained low risk status in middle age, there were still ≈40% who did not. Furthermore, the attributable risk of not having low risk profile as a result of a lack of 5 HLFs was 48%. These results are subject to some limitations. Diet, physical activity, alcohol, and smoking data are self-reported and subject to measurement errors. Misclassification, if anything, may attenuate the associations with the low risk profile. Classifications of healthy diet and higher physical activity level were not based on well-established threshold levels but were selected relative to peers. In addition, because of a lack of data, low sodium intake was not included as part of the healthy diet. For these reasons, the role of HLF on the low CVD risk profile is likely underestimated.

The finding that the prevalence of low risk profiles at Y20 tends to be lower in those who adopted HLFs but did not maintain them over time, as opposed to those who did not adopt HLFs at baseline but adopted and maintained them later, is important. It suggests that people will benefit from improving their lifestyle. However, people benefit the most if they can adopt and maintain a healthy lifestyle throughout the period from young adulthood to middle age. These data also suggest that genetic factors may not be very important in determining a low risk profile. For example, despite the attenuation of association owing to misclassification, for those who had only 0 to 1 HLF, only 3% had a low risk profile at Y20; on the other hand, 61% of those who adopted and maintained 5 HLFs had low risk profiles. The prevalence of the low risk profile increases as the number of HLFs increases. If genetic factors play an important role, we would expect to see a much higher prevalence of low risk profile with 0 to 1 HLFs. Likewise, our data showing the association of HLFs with low risk among those with a family history further support the notion that lifestyle may play a more prominent role than genetics.

Despite the steady decline of CVD mortality rates over the past 40 years, it remains the number 1 killer in the United States. Recent data suggest a flattening of these downward mortality trends, particularly among younger adults 35 to 54 years of age, with evidence for an increase in coronary heart disease death rates among women 35 to 44 years of age. Such data suggest that the decades-long improvements in CVD mortality rates may be on the verge of reversing, perhaps as a result of the effects of the obesity epidemic in the United States. As noted, a large array of data indicate the potency of the low risk profile as a means for substantially avoiding CVD across the lifespan and for improving healthy longevity. Recently, the AHA announced its 2020 Strategic Impact Goal, with the aim of improving the cardiovascular health of all Americans by 20% by the year 2020. The low risk profile (called ideal cardiovascular health factors) and many of the lifestyle factors (called ideal health behaviors) studied in the present analysis form the cornerstone of the AHA’s new definition of cardiovascular health, and the number of these factors in middle age has been shown to be strongly inversely associated with prospective CVD events. The recommendations of Healthy People 2020 use similar definitions and focus on improving cardiovascular health and its components. Clearly, a broad array of public health and public policy strategies involving schools, communities, state and governmental agencies, healthcare systems, and private organizations will be needed to address the societal problems underlying the loss of the low risk profile from young adulthood to middle age. Such policies should be designed to improve the likelihood that individuals can make healthier choices in terms of lifestyles that are associated with long-term improvements in healthy longevity and reductions in healthcare costs.

To achieve these goals, it will be critical to implement public health and individualized approaches to drastically increase the prevalence of the low CVD risk profile in the population. To the best of our knowledge, this is the first study to clearly demonstrate that the pattern of the low CVD risk profile (eg, ideal levels of cardiovascular health factors, including blood pressure, cholesterol, fasting glucose, and never smoking status) in middle age is strongly associated with practicing a healthy lifestyle in young adulthood and maintaining it into middle age. To accomplish the goal of expanding the prevalence of the low risk profile, more
emphasis should be placed on primordial prevention by encouraging the adoption of healthy lifestyles from young ages.

Sources of Funding

This research was funded by contracts N01-HC-48047 through 48050 and N01-HC-95095 from the National Heart, Lung, and Blood Institute, National Institutes of Health.

Disclosures

None.

References


CLINICAL PERSPECTIVE

Low cardiovascular disease risk profile (no prior myocardial infarction and the simultaneous presence of untreated cholesterol <200 mg/dL, untreated blood pressure <120/80 mm Hg, no smoking, and no diabetes mellitus) in middle age has been demonstrated to be associated with lower mortality and morbidity rates, higher life expectancy, lower lifetime risk for cardiovascular disease, higher quality of life, and lower Medicare charges in older age. However, the prevalence of a low risk profile in middle-aged and older people is very low. Using data from the Coronary Artery Risk Development in (Young) Adults (CARDIA) Study, we demonstrated that 5 healthy lifestyle factors—body mass index <25 kg/m², no smoking, vigorous or moderate physical activity at least 5 times per week, no excessive alcohol drinking, and a Dietary Approaches to Stop Hypertension–like diet—during young adulthood to middle age are strongly associated with achievement of the low risk profile in middle age. The study indicated that the more healthy lifestyle factors are adopted and maintained during young adulthood, the higher the prevalence of a low risk profile in middle age. The results also demonstrated that those who did not adopt a healthy lifestyle initially but did so later on could still benefit from the improvement of their lifestyle. These data suggest that physicians should encourage their patients to adopt a healthy lifestyle starting at a young age or to improve their lifestyle as early as possible to maximize the benefits of the low cardiovascular risk profile in terms of healthy longevity.
Healthy Lifestyle Through Young Adulthood and the Presence of Low Cardiovascular Disease Risk Profile in Middle Age: The Coronary Artery Risk Development in (Young) Adults (CARDIA) Study
Kiang Liu, Martha L. Daviglus, Catherine M. Loria, Laura A. Colangelo, Bonnie Spring, Arlen C. Moller and Donald M. Lloyd-Jones

_Circulation_. 2012;125:996-1004; originally published online January 30, 2012; doi: 10.1161/CIRCULATIONAHA.111.060681
_Circulation_ is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
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Supplemental table. Adjusted Prevalence (%) of Low Risk Profile at Y20 by AHEI-based Number of Healthy Lifestyle factors (HLF), Y0 to Y20 among CARDIA Study participants.

<table>
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<th>Number of HLFs*</th>
<th>0-1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>p-trend</th>
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<tbody>
<tr>
<td>All participants†</td>
<td>3.2</td>
<td>14.4</td>
<td>28.6</td>
<td>40.3</td>
<td>54.0</td>
<td>&lt;0.0001</td>
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<td>All participants‡</td>
<td>6.1</td>
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<td>28.5</td>
<td>41.0</td>
<td>55.0</td>
<td>&lt;0.0001</td>
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<td>9.2</td>
<td>14.6</td>
<td>26.4</td>
<td>34.2</td>
<td>&lt;0.0001</td>
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<td>White men§</td>
<td>2.4</td>
<td>14.1</td>
<td>24.7</td>
<td>41.1</td>
<td>45.2</td>
<td>&lt;0.0001</td>
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<tr>
<td>Black women§</td>
<td>3.5</td>
<td>11.8</td>
<td>28.5</td>
<td>38.3</td>
<td>60.2</td>
<td>&lt;0.0001</td>
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<tr>
<td>White women§</td>
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<td>41.2</td>
<td>48.9</td>
<td>66.3</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

* Based on the average of Y0, Y7 and Y20 data.
† Based on imputed data (n=3154) and adjusted for age, race, and sex.
‡ Based on complete data sample (n=2336) and adjusted for age, race, and sex.
§ Age adjusted.