Ideal Cardiovascular Health in Childhood and Cardiometabolic Outcomes in Adulthood
The Cardiovascular Risk in Young Finns Study

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Background—The American Heart Association (AHA) defined a new concept, cardiovascular health, and determined metrics needed to monitor it over time as part of its 2020 Impact Goal definition. Ideal cardiovascular health is defined by the presence of both ideal health behaviors and ideal health factors. The applicability of this concept to a cohort of children and its relationship with cardiometabolic outcomes in adulthood has not been reported.

Methods and Results—The sample comprised 856 participants aged 12 to 18 years (mean age 15.0 years) from the Cardiovascular Risk in Young Finns Study cohort. Participants were followed up for 21 years since baseline (1986) and had data available concerning health factors and behaviors in childhood and cardiometabolic outcomes in adulthood (2007). The number of ideal cardiovascular health metrics present in childhood was associated with reduced risk of hypertension (odds ratio [95% confidence interval] 0.66 [0.52–0.85], \( P = 0.001 \)), metabolic syndrome (0.66 [0.52–0.77], \( P < 0.001 \)), high low-density lipoprotein cholesterol (0.66 [0.52–0.85], \( P = 0.001 \)), and high-risk carotid artery intima-media thickness (0.75 [0.60–0.94], \( P = 0.01 \)) in adulthood. All analyses were age and sex adjusted, and the results were not altered after additional adjustment with socioeconomic status.

Conclusions—The number of ideal cardiovascular health metrics present in childhood predicts subsequent cardiometabolic health in adulthood. Our findings suggest that pursuit of ideal cardiovascular health in childhood is important to prevent cardiometabolic outcomes in adulthood. (Circulation. 2012;125:1971-1978.)

Key Words: cardiovascular diseases ■ epidemiology ■ risk factors ■ children

The clinical events of cardiovascular disease (CVD), such as myocardial infarction and stroke, are end points of gradual progression of atherosclerosis. Extensive evidence indicates that adults with no CVD risk factors and healthy lifestyles experience low rates of CVD events.1–4 The atherosclerotic process begins early in life, but clinical manifestations tend to occur decades later.5 It has been shown that traditional CVD risk factors already present in childhood predict the occurrence of preclinical carotid atherosclerosis in adulthood.6–8

Editorial see p 1955
Clinical Perspective on p 1978

In January 2010, the American Heart Association (AHA) released its 2020 Impact Goals, in which the construct of cardiovascular health and the metrics needed to monitor it over time were defined.9 Ideal cardiovascular health, by the AHA’s definition, is the simultaneous presence of 4 ideal health behaviors (never smoked or quit >12 months ago in adults and never tried or never smoked a whole cigarette in children; body mass index [BMI] <25 kg/m2 in adults and <85th percentile in children; physical activity at goal levels; and diet consistent with current guideline recommendations) and 3 ideal health factors (untreated total cholesterol <5.17 mmol/L [<200 mg/dL] in adults and <4.40 mmol/L [<170 mg/dL] in children; untreated blood pressure <120 mm Hg/<80 mm Hg in adults and <90th percentile in children; and untreated fasting plasma glucose <5.6 mmol/L [<100 mg/dL]). The report emphasized that in the long term,
monitoring of available data in children will be critical to increase the prevalence of ideal cardiovascular health and to maintain it through middle and older ages.9

Recent studies have described the low community prevalence of ideal cardiovascular health10,11 and its relationship with CVD incidence12 among adults. However, studies concerning ideal cardiovascular health in childhood and its relationship with cardiometabolic health in adulthood are lacking. Using data from the Cardiovascular Risk in Young Finns Study, we examined whether the AHA construct of ideal cardiovascular health in childhood is associated with hypertension, dyslipidemia, metabolic syndrome (MetS), type 2 diabetes mellitus (T2DM), and carotid intima-media thickness (IMT) 21 years later in adulthood. These data may have implications in the prevention of CVD.

Methods

Participants

The Cardiovascular Risk in Young Finns Study is an ongoing multicenter follow-up study to assess risk factors underlying CVD. The first cross-sectional survey was conducted in 1980, when 3596 individuals aged 3 to 18 years participated.12 These participants were randomly chosen from the national register of the study areas. Since 1980, several follow-up studies have been conducted. The latest 27-year follow-up survey was performed in 2007, when 2204 (aged 30–45 years) of the original participants attended. For the present report, we chose the baseline year of 1986 because it was the first follow-up at which glucose values were measured. The present sample comprised 856 participants aged 12 to 18 years who had complete risk factor data available from baseline, had undergone ultrasound examinations and laboratory measurements during the 2007 survey, and therefore had data available concerning cardiometabolic outcomes in adulthood. All participants provided written informed consent, and the study was approved by local ethics committees.

Metrics for Cardiovascular Health

Where possible, we followed the metrics described by the AHA.9 In children, BMI and health factors such as blood pressure normally change with age, growth, and development. A single threshold to identify elevated risk across childhood is not appropriate, which is why the AHA recommended the use of percentiles to define higher-risk levels for BMI and blood pressure in childhood.9 All percentile limits used in the present study are age and sex specific.

Health Factors

For the determination of serum lipoprotein and triglyceride levels, venous blood samples were drawn after an overnight fast. All determinations were performed with standard methods reported previously.13,14 In childhood, total cholesterol status was defined as ideal (<4.40 mmol/L (<170 mg/dL) or nonideal ≥4.40 mmol/L (≥170 mg/dL) and in adulthood as ideal (<5.17 mmol/L (<200 mg/dL) or nonideal ≥5.17 mmol/L (≥200 mg/dL).9

Blood pressure was measured from the brachial artery with a random zero sphygmomanometer in childhood and adulthood. The average of 3 readings was used in the analysis to classify blood pressure status in childhood as ideal (systolic blood pressure <90th percentile and diastolic blood pressure <90th percentile) or nonideal (systolic blood pressure ≥90th percentile or diastolic blood pressure ≥90th percentile) and in adulthood as ideal (systolic blood pressure <120 mm Hg and diastolic blood pressure <80 mm Hg) or nonideal (systolic blood pressure ≥120 mm Hg or diastolic blood pressure ≥80 mm Hg).

Fasting plasma glucose concentrations were analyzed enzymatically and classified in childhood and adulthood as ideal (<5.6 mmol/L (<100 mg/dL) or nonideal ≥5.6 mmol/L (≥100 mg/dL), respectively.9

In the absence of a consensus pediatric MetS definition,13 we used the definition that we have previously shown to predict adult outcomes.16 Participants were categorized as having MetS if they had any 3 of the following 5 components: BMI ≥75th percentile, systolic or diastolic blood pressure ≥75th percentile, high-density lipoprotein cholesterol ≤25th percentile, triglycerides ≥75th percentile, or glucose ≥75th percentile.

Health Behaviors

Height and weight were measured, and BMI calculated as BMI = weight (kg)/(height (m)^2). BMI was classified in childhood as ideal <85th percentile or nonideal ≥85th percentile and in adulthood as ideal <25 kg/m^2 or nonideal ≥25 kg/m^2.9

In childhood, information on dietary habits was obtained with a nonquantitative food frequency questionnaire. Subjects answered the questions themselves, assisted by their parents when necessary. To examine the frequency of consumption of fruits, vegetables, fish or fish products, and soft drinks, the subjects were asked to complete a questionnaire on habitual dietary choices for the past month with 6 response categories: 1= daily, 2= almost every day, 3= a couple of times per week, 4= about once a week, 5= a couple of times per month, and 6= more seldom. We classified subjects as having an ideal fruit and vegetable consumption if they consumed both fruits and vegetables daily. Subjects who consumed fish or fish products a couple of times per week or more frequently were classified as having ideal fish consumption. Subjects who consumed soft drinks a couple of times per week or less frequently were classified as having ideal soft drink consumption. Subjects who had 2 to 3 of these 3 ideal diet components were categorized as having an ideal childhood healthy diet score, and subjects with 0 to 1 ideal diet components were classified as having a nonideal childhood healthy diet score.

Although the quantitative amounts of fruits and vegetables, fish, and soft drinks consumed could not be derived, nor was it possible to measure the intakes of sodium and fiber-rich whole grain that the AHA recommends, the questionnaire provided approximations of ideal and nonideal child healthy diet score.

In adulthood, a more detailed quantitative food frequency questionnaire that provided an estimate of food consumption in grams per day was introduced. Intake goals defined by the AHA are expressed for a 2000-kcal diet,9 so we first scaled the intake goals according to subjects’ total energy intake. We then categorized achievement of the 5 AHA ideal dietary goals: ≥4.5 cups per day of fruits and vegetables (approximated as 450 g/d), ≥two 3.5-oz servings per week of fish (approximated as 1 oz/d), ≥three 1-oz servings per day of whole grains (approximated as 3 oz/d), sodium <1500 mg/d, and ≤450 kcal (36 oz) of sugar-sweetened beverages per week (approximated as 5 oz/d). Subjects who had 4 to 5 of these 5 ideal diet components were categorized as having an ideal adult healthy diet score and subjects with 0 to 3 ideal diet components as having a nonideal adult healthy diet score.

In childhood, smoking was assessed in subjects aged ≥12 years, and thus, children aged 9 years were excluded from this study. Smoking data were collected in connection with the medical examination in a solitary room where participants could respond confidentially and undisturbed. Subjects who reported that they had never smoked a whole cigarette were categorized as having an ideal child smoking status and subjects who had smoked 1 or more cigarettes as having a nonideal child smoking status. In adulthood, subjects were classified as current smokers (nonideal) and never or former smokers (ideal).

Physical activity was assessed by a self-report questionnaire. In childhood, subjects answered the questions themselves, with their parents’ assistance as necessary. In childhood and adulthood, the physical activity questionnaire consisted of the following variables: Intensity of physical activity, frequency of moderate or vigorous activity, and hours spent on moderate or vigorous activity per week.

The AHA’s definition of ideal physical activity in childhood is ≥60 minutes of moderate or vigorous activity every day (approximated as ≥7 hours of moderate or vigorous activity per week in the present study), and in adulthood, ≥150 min/wk of moderate-intensity activity or ≥75 min/wk of vigorous intensity or ≥150 min/wk of...
moderate plus vigorous activity (approximated as ≥1 h/wk vigorous intensity or ≥2–3 h/wk moderate intensity or ≥2–3 h/wk moderate plus vigorous activity in the present study). Subjects who did not reach these values were classified as having a nonideal physical activity level.

Indices of the Ideal Cardiovascular Health
From the individual health factors and behaviors described above, we generated corresponding AHA indices. The ideal child cardiovascular health index corresponds to the number of ideal health factors and behaviors present at the baseline survey (1986). The ideal adult cardiovascular health index corresponds to the number of ideal health factors and behaviors present at the 2007 survey. In analyses, we used the ideal cardiovascular health indices as continuous variables (index 0–7). Change in ideal cardiovascular health index indicates change between the ideal child and the ideal adult cardiovascular health index.

Socioeconomic Status and Pack-Years of Smoking
Data on parental study years were assessed by a self-report questionnaire. The length of the parent’s education was considered as an indicator of childhood socioeconomic status. Pack-years of smoking were calculated in 2007 by multiplying years of smoking by the average number of cigarettes smoked per day.

Cardiometabolic Outcomes
In adulthood, the harmonized definition for MetS was used in the present study.17 MetS was diagnosed if the subject had at least 3 of the following 5 factors: (1) Waist circumference ≥102 cm for males and ≥88 cm for females; (2) raised triglycerides (>1.7 mmol/L [>150 mg/dL]), or specific treatment for this lipid abnormality; (3) reduced high-density lipoprotein cholesterol (<1.0 mmol/L [<39 mg/dL]) in males and <1.3 mmol/L [<50 mg/dL] in females), or specific treatment for this lipid abnormality; (4) raised blood pressure (blood pressure ≥130/85 mm Hg), or treatment of previously diagnosed hypertension; and (5) raised fasting plasma glucose ≥5.6 mmol/L (100 mg/dL), or previously diagnosed T2DM.

Participants were classified as having T2DM if they had fasting plasma glucose of ≥7.0 mmol/L, reported use of oral glucose-lowering medication or insulin but had not reported having type 1 diabetes mellitus, or reported a diagnosis of T2DM by a physician. Participants were classified as having hypertension if they had a systolic blood pressure of ≥140 mm Hg or a diastolic blood pressure of ≥90 mm Hg, or if they reported use of blood-pressure lowering medication. National Cholesterol Education Project guidelines for low-density lipoprotein (LDL) cholesterol (≥4.14 mmol/L [160 mg/dL]), high-density lipoprotein cholesterol (<1.036 mmol/L [40 mg/dL]), and triglycerides (≥2.6 mmol/L [200 mg/dL]) were used to define dyslipidemia.18

Carotid Artery IMT
Ultrasound studies were performed with Sequoia 512 ultrasound mainframes (Acuson) with 13.0-MHz linear-array transducers. Ultrasound studies were performed by trained sonographers according to a standardized protocol. Measurements were made offline from stored digital images. All ultrasound scans were analyzed by 1 reader blinded to the subjects’ details. Carotid artery IMT was measured as described in detail previously.6 Mean IMT was derived from a minimum of 4 IMT measurements from the posterior (far) wall of the left carotid artery ∼10 mm proximal to the carotid bifurcation. Participants who had a plaque in the carotid artery or whose carotid IMT was >90th percentile were classified as having a high-risk IMT.

Statistical Analyses
To study differences between characteristics of participants and those lost to follow-up, we used unadjusted and age- and sex-adjusted linear and logistic regression models. To examine the associations of individual ideal child and adult cardiovascular health factors and behaviors and serum lipids in childhood and adulthood with the ideal child cardiovascular health index, we used age- and sex-adjusted linear regression for continuous outcomes and age- and sex-adjusted logistic regression for binary outcomes. Continuous variables were described by means±SDs and binary variables as percentages. To study how the ideal child cardiovascular health index was associated with cardiometabolic outcomes in 2007, we examined age- and sex-adjusted odds ratios for the ideal child cardiovascular health index using logistic regression. To study associations of ideal child cardiovascular health index and change in ideal cardiovascular health index with carotid IMT, we used age- and sex-adjusted linear regression to calculate probability value for trend. The statistical tests were performed with SAS version 9.2 (SAS Institute, Inc, Cary, NC). Statistical significance was inferred at a 2-tailed P<0.05.

Results
Characteristics of the Study Subjects
Characteristics of participants and those lost to follow-up in 2007 are compared in Table 1. Those lost to follow-up in 2007 (n=560) were more often males and younger than participants (n=856). No differences were observed in ideal child cardiovascular health factors, health behaviors, or serum lipids between participants and those lost to follow-up.

Participants met on average 3.5±1.0 of all 7 ideal metrics (Table 2). None of the participants met 0 or all 7 metrics of the ideal child cardiovascular health index. There was no difference between girls and boys exhibiting ideal metrics (3.5±1.0 versus 3.6±1.0 respectively, P=0.37). Those with more ideal metrics tended to be younger at baseline. Significant age- and sex-adjusted trends for ideal child cardiometabolic health index groups 1 to 6 were observed for all ideal child health behaviors (BMI, physical activity, healthy diet score, and smoking status) and ideal child health factors (systolic and diastolic blood pressure, glucose level, and total cholesterol level), as well as for LDL cholesterol and triglycerides in childhood. Significant age- and sex-adjusted trends across the ideal child cardiovascular health index groups were also observed for adult measures of BMI, ideal smoking status, systolic and diastolic blood pressure, total cholesterol, LDL cholesterol, and triglycerides. In addition, the ideal child cardiovascular health index was associated with the ideal adult cardiovascular health index in both unadjusted (β±SE 0.37±0.05, P<0.001) and age-and sex-adjusted (β±SE 0.37±0.05, P<0.001) linear regression models.

In childhood, the ideal cardiovascular health metrics were met by 85.6% of the participants for BMI, 6.9% for physical activity, 24.3% for healthy diet score, 22.4% for smoking status, 82.2% for blood pressure, 97.4% for glucose level, and 33.2% for total cholesterol level.

Cardiometabolic Outcomes
The ideal child cardiovascular health index was associated with ideal adult blood pressure (odds ratio [95% confidence interval] 1.29 [1.12–1.48]), total cholesterol (1.39 [1.20–1.60]), and glucose status (1.29 [1.10–1.51]). Table 3 shows the age- and sex-adjusted odds ratios for the ideal child cardiovascular health index for prediction of cardiometabolic outcomes in adulthood with a follow-up time of 21 years. Ideal child cardiovascular health index was significantly associated with reduced odds of hypertension, MetS, high LDL cholesterol, and high triglycerides. The results were not
altered after additional adjustment for childhood socioeconomic status (data not shown). Adjustment for pack-years of smoking did not change the other results, but the association with high triglycerides became nonsignificant. There was a linear association between ideal child cardiovascular health index and the cardiometabolic outcomes in adulthood.

### Intima-Media Thickness

Mean adult carotid IMTs among the ideal child cardiovascular health index groups are shown in the Figure. The difference in adult carotid IMT between ideal child cardiovascular health groups 1 and 6 was 0.067 mm. In age- and sex-adjusted linear regression models, the ideal child cardiovascular health index was inversely associated with adult carotid IMT treated as a continuous (Figure, panel B) or categorized variable (Table 3). The effect of the child ideal cardiovascular health index on adult carotid IMT remained significant ($\beta \pm SE = -0.011 \pm 0.003, P=0.001$) after adjustment for change in the ideal cardiovascular health index between childhood and adulthood. In addition, the health index change was associated with IMT in this analysis ($\beta \pm SE = -0.009 \pm 0.002, P<0.001$). The results were not altered after additional adjustment for childhood socioeconomic status or pack-years of smoking (data not shown).

### Sensitivity Analyses

We made 3 additional analyses. First, because few participants met 1 or 6 ideal cardiovascular health metrics in childhood, we combined ideal child cardiovascular health index groups 1 and 2 and groups 5 and 6. Second, we chose the baseline year of the present study to be the same as the baseline year of the Cardiovascular Risk of Young Finns Study (1980) and considered all participants (aged 12–18 years, $n=1090$) to have an ideal fasting plasma glucose status in childhood because the glucose values were not measured in 1980. Third, we used age- and sex-specific percentiles to define ideal and nonideal levels not only for BMI and blood pressure but also for total cholesterol in childhood. We classified total cholesterol status in childhood as ideal $<$80th percentile or nonideal $\geq$80th percentile. In all of these sensitivity analyses, the main results were similar to those shown.

### Discussion

In the present study, we applied the AHA 2020 Impact Goal metrics to a long-term prospective study of cardiovascular health in children. To the best of our knowledge, the present study is the first to report the application of this construct to a cohort of children and to investigate its relationship with cardiometabolic outcomes in adulthood. We observed that the AHA metrics for children predict subsequent cardiometabolic health in adulthood. The ideal child cardiovascular health index, generated from the individual health factors and behaviors, was associated with reduced risk of hypertension, high LDL cholesterol, MetS, and high-risk IMT in adulthood. We and others have previously shown associations between childhood risk factors and carotid IMT in adulthood. In these studies, however, either fewer metrics were used or individual risk factors were studied, whereas we used AHA-defined clusters of health factors and behaviors. Cardiometabolic risk factors tend to occur together more frequently than expected by chance alone, and clustering of risk factors is thought to be a better measure of cardiovascular health in children. We have recently documented that pediatric MetS and high BMI alone predict high carotid IMT and T2DM in adulthood. Few population-based studies have prospec-

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**Table 1. Attrition Analysis**

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Age, y, mean (SD)</td>
<td>15.0 (2.5)</td>
<td>14.6 (2.3)</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Male, %</td>
<td>42.4</td>
<td>57.5</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Ideal child health behaviors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI, kg/m², mean (SD)</td>
<td>20.1 (2.9)</td>
<td>20.2 (3.5)</td>
<td>0.66</td>
<td>0.08</td>
</tr>
<tr>
<td>Ideal physical activity, %</td>
<td>6.9</td>
<td>6.7</td>
<td>0.90</td>
<td>0.51</td>
</tr>
<tr>
<td>Ideal healthy diet score, %</td>
<td>24.3</td>
<td>21.0</td>
<td>0.19</td>
<td>0.23</td>
</tr>
<tr>
<td>Never smoked whole cigarette, %</td>
<td>22.4</td>
<td>22.4</td>
<td>0.99</td>
<td>0.81</td>
</tr>
<tr>
<td>Ideal child health factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic BP, mm Hg, mean (SD)</td>
<td>114.1 (11.5)</td>
<td>114.5 (12.1)</td>
<td>0.50</td>
<td>0.41</td>
</tr>
<tr>
<td>Diastolic BP, mm Hg, mean (SD)</td>
<td>64.5 (9.1)</td>
<td>65.1 (10.5)</td>
<td>0.33</td>
<td>0.07</td>
</tr>
<tr>
<td>Glucose, mmol/L, mean (SD)</td>
<td>4.7 (0.8)</td>
<td>4.7 (0.7)</td>
<td>0.89</td>
<td>0.60</td>
</tr>
<tr>
<td>Total cholesterol, mmol/L, mean (SD)</td>
<td>4.87 (0.94)</td>
<td>4.83 (0.98)</td>
<td>0.49</td>
<td>0.84</td>
</tr>
<tr>
<td>Other factors in childhood</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LDL cholesterol, mmol/L, mean (SD)</td>
<td>2.95 (0.84)</td>
<td>2.95 (0.92)</td>
<td>0.97</td>
<td>0.80</td>
</tr>
<tr>
<td>HDL cholesterol, mmol/L, mean (SD)</td>
<td>1.50 (0.28)</td>
<td>1.46 (0.28)</td>
<td>0.04</td>
<td>0.15</td>
</tr>
<tr>
<td>Triglycerides, mmol/L, mean (SD)</td>
<td>0.94 (0.38)</td>
<td>0.93 (0.32)</td>
<td>0.77</td>
<td>0.78</td>
</tr>
<tr>
<td>MetS, %</td>
<td>18.8</td>
<td>22.5</td>
<td>0.13</td>
<td>0.19</td>
</tr>
</tbody>
</table>

BMI indicates body mass index; BP, blood pressure; LDL, low-density lipoprotein; HDL, high-density lipoprotein; and MetS, metabolic syndrome.
tively examined the usefulness of childhood lipid classifications in predicting adult high-risk levels. Also, blood pressure is shown to track from childhood to adulthood. In the present study, we showed that the new AHA definition of cardiovascular health in childhood reflects well the subsequent risk of hypertension, MetS, and high LDL cholesterol in adulthood.

Few studies have been conducted concerning the AHA’s new definition of ideal cardiovascular health. Bambas et al reported a very low prevalence of ideal cardiovascular health in a middle-aged community-based study population in the United States. Folsom et al described that only 0.1% had ideal cardiovascular health in a community-based sample in the United States, and those who had the best levels of cardiovascular health experienced relatively few events. Our findings are consistent with these observations, even though in the present study, we applied the AHA construct of ideal cardiovascular health to a cohort of children. None of the 856 children examined in 1986 (aged 12–18 years) met all 7 AHA-defined cardiovascular health metrics and thus had ideal cardiovascular health. The level of ideal physical activity was the most difficult to achieve in the present study, with only 6.9% of the subjects having ideal physical activity status. Recently, similar results for meeting the goal of 60 minutes of physical activity per day have been reported in the United States in 12- to 19-year-olds using accelerometers.

Carotid IMT has been used as a surrogate marker of cardiovascular health, as an alternative to the use of cardiovascular events as disease end points. Hypertension, MetS, and high LDL cholesterol are known to predict independently

### Table 2. Distribution of Individual Cardiovascular Health Metrics

<table>
<thead>
<tr>
<th>Metric</th>
<th>All</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>P for Trend*</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>856</td>
<td>15</td>
<td>102</td>
<td>312</td>
<td>294</td>
<td>115</td>
<td>18</td>
<td>0.003</td>
</tr>
<tr>
<td>Age at baseline, mean (SD)</td>
<td>15.0 (2.5)</td>
<td>15.4 (2.7)</td>
<td>15.2 (2.5)</td>
<td>15.2 (2.4)</td>
<td>15.0 (2.5)</td>
<td>14.5 (2.3)</td>
<td>14.2 (2.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Male, %</td>
<td>42.4</td>
<td>46.7</td>
<td>38.2</td>
<td>40.1</td>
<td>45.6</td>
<td>45.2</td>
<td>33.3</td>
<td>0.37</td>
</tr>
<tr>
<td>BMI, kg/m², mean (SD)</td>
<td>20.1 (2.9)</td>
<td>25.2 (3.3)</td>
<td>22.4 (3.3)</td>
<td>20.2 (2.7)</td>
<td>19.4 (2.4)</td>
<td>19.0 (2.1)</td>
<td>19.3 (1.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Ideal physical activity, %</td>
<td>6.9</td>
<td>0.0</td>
<td>1.0</td>
<td>2.2</td>
<td>6.1</td>
<td>22.6</td>
<td>38.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Ideal healthy diet score, %</td>
<td>24.3</td>
<td>0.0</td>
<td>6.9</td>
<td>9.9</td>
<td>27.6</td>
<td>63.5</td>
<td>88.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Ideal smoking status, %</td>
<td>22.4</td>
<td>0.0</td>
<td>8.8</td>
<td>9.9</td>
<td>28.2</td>
<td>47.0</td>
<td>83.3</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
| BMI indicates body mass index; BP, blood pressure; LDL, low-density lipoprotein; and HDL, high-density lipoprotein.
| *All child and adult cardiovascular health metrics adjusted for age and sex.
the subsequent risk of myocardial infarction and stroke. In the present study, participants who exhibited a high number of ideal cardiovascular health metrics in childhood had thinner carotid IMT and were at lower risk to develop hypertension, MetS, and dyslipidemia (high LDL cholesterol and high triglycerides) in adulthood. These results suggest a major impact of ideal child cardiovascular health index on subsequent risk of CVD in the present study population. In a previous report from the Cardiovascular Risk in Young Finns Study, we showed that carotid IMT increases $0.0057 \pm 0.0004$ mm/y in healthy young adults. In the present study, we observed a difference of 0.067 mm in adult carotid IMT between ideal child cardiovascular health index groups 1 and 6. Using the vascular age concept, this corresponds to 11.8 years, which means that participants with only 1 ideal health metric were almost 12 years older in terms of vascular age than those with 6 metrics.

The present study has limitations. First we are not currently able to study associations with the clinical outcome of cardiovascular events. Instead, we used carotid artery IMT and cardiometabolic outcomes as surrogate markers of cardiovascular health. Second, even though measurement of major risk factors is well standardized and therefore quite generalizable from study to study, measurement of diet and physical activity is not. In childhood, information on dietary habits was obtained with a nonquantitative food frequency questionnaire that provided an estimate of food consumption in grams per day was used. Physical activity was assessed by a subjective method both in childhood and adulthood. Third, because the present study cohort was racially homogeneous, the generalizability of our results is limited to white European subjects. A potential limitation is loss to follow-up; however, the baseline cardiovascular health metrics (in 1986) were similar among participants and those lost to follow-up. Thus, the present study cohort appears to be representative of the original population. Finally, an observational study design cannot conclusively differentiate whether the observed associations between ideal child cardiovascular health index and adult outcomes are caused by specific effects of youth behaviors and risk marker levels or their lifelong tracking to adulthood. The strengths of the present study include the longitudinal study design and the long follow-up of the participants, who were very well phenotyped in childhood and adulthood.

In summary, the number of ideal cardiovascular health metrics present in childhood predicted subsequent cardiometabolic health in adulthood independent of change in the index during follow-up. The ideal child cardiovascular health index was directly associated with the index in adulthood, which highlights the importance of promoting a healthy lifestyle early in life. In prior reports, we observed that elevated LDL cholesterol and blood pressure in youth were associated with increased IMT in adulthood, independent of adult levels. Conversely, childhood overweight-related risks for various outcomes (hypertension, high-risk IMT, dyslipidemia, T2DM) appeared to be reversible among those individuals who became nonobese adults. Therefore, the quality and quantity of risk exposure in youth that cause permanent effects on adult outcomes are still unknown, and this may vary between the outcomes. In the present analysis, we addressed the question of independence by taking into account the change in ideal cardiovascular health index between childhood and adulthood as a covariate in predicting carotid IMT. Both the baseline index and the change appeared to be independently associated with subclinical atherosclerosis. We believe that the implication of this finding is that an improvement of the components of the index is beneficially associated with adult cardiovascular health. The findings of the present study are in line with the recent recommendation of maintaining a low-risk status from childhood into young

addition, the intake of sodium and fiber-rich whole grain, which the AHA also includes in their metrics, could not be derived in childhood. In adulthood, a more detailed quantitative food frequency questionnaire that provided an estimate of food consumption in grams per day was used. Physical activity was assessed by a subjective method both in childhood and adulthood. Third, because the present study cohort was racially homogeneous, the generalizability of our results is limited to white European subjects. A potential limitation is loss to follow-up; however, the baseline cardiovascular health metrics (in 1986) were similar among participants and those lost to follow-up. Thus, the present study cohort appears to be representative of the original population. Finally, an observational study design cannot conclusively differentiate whether the observed associations between ideal child cardiovascular health index and adult outcomes are caused by specific effects of youth behaviors and risk marker levels or their lifelong tracking to adulthood. The strengths of the present study include the longitudinal study design and the long follow-up of the participants, who were very well phenotyped in childhood and adulthood.

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### Table 3. Age- and Sex-Adjusted Odds Ratios and 95% Confidence Intervals for AHA Ideal Child Cardiovascular Health Index for Prediction of Cardiometabolic Outcomes in Adulthood

<table>
<thead>
<tr>
<th>Health Metric</th>
<th>OR</th>
<th>95% CI</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypertension</td>
<td>0.66</td>
<td>0.54–0.80</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Metabolic syndrome</td>
<td>0.63</td>
<td>0.52–0.77</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Type 2 diabetes mellitus</td>
<td>0.70</td>
<td>0.32–1.52</td>
<td>0.37</td>
</tr>
<tr>
<td>High LDL cholesterol</td>
<td>0.66</td>
<td>0.52–0.85</td>
<td>0.001</td>
</tr>
<tr>
<td>Low HDL cholesterol</td>
<td>0.94</td>
<td>0.79–1.13</td>
<td>0.54</td>
</tr>
<tr>
<td>High triglycerides</td>
<td>0.80</td>
<td>0.65–0.99</td>
<td>0.04</td>
</tr>
<tr>
<td>High-risk IMT</td>
<td>0.75</td>
<td>0.60–0.94</td>
<td>0.01</td>
</tr>
</tbody>
</table>

AHA indicates American Heart Association; OR, odds ratio; CI, confidence interval; LDL, low-density lipoprotein; HDL, high-density lipoprotein; and IMT, intima-media thickness.

Odds ratios are for a 1-unit increase in ideal cardiovascular health index.

In summary, the number of ideal cardiovascular health metrics present in childhood predicted subsequent cardiometabolic health in adulthood independent of change in the index during follow-up. The ideal child cardiovascular health index was directly associated with the index in adulthood, which highlights the importance of promoting a healthy lifestyle early in life. In prior reports, we observed that elevated LDL cholesterol and blood pressure in youth were associated with increased IMT in adulthood, independent of adult levels. Conversely, childhood overweight-related risks for various outcomes (hypertension, high-risk IMT, dyslipidemia, T2DM) appeared to be reversible among those individuals who became nonobese adults. Therefore, the quality and quantity of risk exposure in youth that cause permanent effects on adult outcomes are still unknown, and this may vary between the outcomes. In the present analysis, we addressed the question of independence by taking into account the change in ideal cardiovascular health index between childhood and adulthood as a covariate in predicting carotid IMT. Both the baseline index and the change appeared to be independently associated with subclinical atherosclerosis. We believe that the implication of this finding is that an improvement of the components of the index is beneficially associated with adult cardiovascular health. The findings of the present study are in line with the recent recommendation of maintaining a low-risk status from childhood into young

### Figure

A. Mean values (SEM) of unadjusted adult carotid intima-media thickness (IMT) in different ideal child cardiovascular health index groups. B. Mean values (SEM) of age- and sex-adjusted adult carotid IMT in different ideal child cardiovascular health index groups.
adulthood. Results from the Special Turku Coronary Risk Factor Intervention Project for children (STRIP) study have indeed shown that a family-based dietary intervention has beneficial long-term effects on lipids and vascular function among children. These data provide support for intervention programs that target health behaviors and factors in childhood.

Acknowledgments

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Disclosures

None.

References


The pediatric origin of atherosclerosis is now well accepted. Atherosclerosis is associated with early risk factor levels and is progressive. The clinical manifestations may occur even decades later. Recently, the American Heart Association (AHA) defined a new concept, cardiovascular health, and determined metrics needed to monitor it over time, as part of its 2020 Impact Goal definition. The report emphasized that monitoring of available data in children will be critical to increase the prevalence of ideal cardiovascular health and to maintain it through middle and older ages in the long term. In the present analysis, based on the Cardiovascular Risk in Young Finns Study cohort, we applied the construct of ideal cardiovascular health to a long-term prospective study of cardiovascular health in children and investigated its relationship with cardiometabolic outcomes in adulthood. The sample comprised 856 participants aged 12 to 18 years at baseline who were reexamined 21 years later. We observed that children who exhibited a high number of ideal cardiovascular health metrics were at lower risk to develop hypertension, metabolic syndrome, and dyslipidemia (high low-density lipoprotein cholesterol and high triglycerides) and had thinner carotid intima-media thickness in adulthood. Our findings suggest that pursuit of ideal cardiovascular health in childhood is important to prevent cardiometabolic outcomes in adulthood and provide support for intervention programs that target health factors and behaviors in childhood.

CLINICAL PERSPECTIVE

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