Cardiovascular diseases (CVDs) are largely preventable; behaviors such as smoking, physical inactivity, and eating an unhealthy diet raise the risk for CVDs. In the Special Turku Coronary Risk Factor Intervention Project for Children (STRIP) study, repeated saturated fat–oriented dietary counseling was introduced in infancy and maintained until 20 years of age. The counseling has led to favorable changes in diet and, for example, lower low-density lipoprotein cholesterol and blood pressure, as well as diminished clustering of overweight-related risk factors in the intervention children.

In 2010, the American Heart Association released a set of 7 cardiovascular health metrics for children and adults to describe ideal cardiovascular health. In the AHA’s concept, cardiovascular health as opposed to disease was highlighted. The metrics used to indicate cardiovascular health included 4 health behaviors and 3 health factors. The behavioral criteria were nonsmoking, being physically active, having normal body mass index (BMI), and eating a healthy diet. Normal blood pressure, total cholesterol, and plasma glucose levels were also considered. The association between these metrics and vascular health was examined in the STRIP study.

Methods and Results—In adolescents participating in the longitudinal, randomized, atherosclerosis-prevention STRIP study, complete data on ideal cardiovascular health metrics were available at 15 (n=394), 17 (n=376), and 19 (n=298) years of age. Aortic intima-media thickness and elasticity were measured with ultrasonography at the same ages. None of the adolescents had all 7 ideal cardiovascular health metrics. At least 5 ideal metrics was found in 60.2%, 45.5%, and 34.2% of the adolescents at 15, 17, and 19 years of age, respectively. Adolescents in the control group had an increased risk of low ideal cardiovascular health (≤3 metrics) compared with the intervention adolescents (risk ratio=1.35; 95% confidence interval=1.04–1.77). The number of ideal cardiovascular health metrics was inversely associated with aortic intima-media thickness (\(P<0.0001\)) and directly associated with elasticity (\(P=0.045\)). The risk of having high intima-media thickness (>85th percentile) was nearly 2-fold in adolescents with a low number of metrics (≤3) compared with those with a higher score (risk ratio=1.78; 95% confidence interval=1.31–2.43).

Conclusions—Ideal cardiovascular health as determined by the AHA can be promoted in adolescents. The ideal cardiovascular health concept is beneficially associated with vascular health already in adolescence, supporting the relevance of targeting these metrics as part of primordial prevention.


Key Words: atherosclerosis ■ child ■ prevention and control ■ ultrasonography

Cardiovascular diseases (CVDs) are largely preventable; behaviors such as smoking, physical inactivity, and eating an unhealthy diet raise the risk for CVDs. In the Special Turku Coronary Risk Factor Intervention Project for Children (STRIP) study, repeated saturated fat–oriented dietary counseling was introduced in infancy and maintained until 20 years of age. The counseling has led to favorable changes in diet and, for example, lower low-density lipoprotein cholesterol and blood pressure, as well as diminished clustering of overweight-related risk factors in the intervention children.

Clinical Perspective on p 2096

In 2010, the American Heart Association released a set of 7 cardiovascular health metrics for children and adults to describe ideal cardiovascular health. In the AHA’s concept, cardiovascular health as opposed to disease was highlighted. The metrics used to indicate cardiovascular health included 4 health behaviors and 3 health factors. The behavioral criteria were nonsmoking, being physically active, having normal body mass index (BMI), and eating a healthy diet. Normal blood pressure, total cholesterol, and plasma glucose levels were also considered.
levels indicated ideal health factors. Ideal cardiovascular health was defined as having all 7 metrics of the behaviors and factors.

The prevalence of ideal cardiovascular health is reported to be very low in adults\textsuperscript{8,10} and children.\textsuperscript{11} The concept is associated with CVD incidence\textsuperscript{12} and with CVD and all-cause mortality in adults.\textsuperscript{10,13,14} We recently reported in the Cardiovascular Risk in Young Finns Study that a higher number of the ideal cardiovascular health metrics in childhood was associated with a reduced risk of hypertension, metabolic syndrome, high low-density lipoprotein cholesterol, and high-risk carotid intima-media thickness (IMT) 21 years later in adulthood.\textsuperscript{11} Longitudinal data on the ideal cardiovascular health metrics in adolescence are lacking. The association of the number of ideal cardiovascular health metrics with vascular IMT and elasticity—surrogate markers of atherosclerosis—is also unknown in adolescents. We therefore investigated the prevalence of ideal cardiovascular health and its association with vascular IMT and elasticity in individuals studied repeatedly at the 15, 17, and 19 years of age. We also studied the effect of the STRIP study intervention on reaching the goal of ideal cardiovascular health.

Methods

Study Design and Participants

The STRIP trial is a prospective, randomized study that aims to prevent atherosclerosis beginning in infancy.\textsuperscript{2,4} In brief, between February 1990 and June 1992, families of 6-month-old infants were recruited at well-baby clinics in Turku, Finland. At 7 months of age, 1062 infants (56.5\% of the eligible age cohort) were randomly allocated to a dietary intervention (n=540) or control (n=522) group. The intervention group received individualized dietary and subsequently antismoking counseling at least biannually until 20 years of age. The study was approved by the Joint Commission on Ethics of the Turku University and the Turku University Central Hospital. Written informed consent was obtained from the parents in the beginning of the study and from the adolescents at 15 years of age.

This study comprised adolescents who had complete data on the metrics included in the ideal cardiovascular health concept at 15 (n=394, 75\% of the cohort), 17 (n=376, 78\%), or 19 (n=298, 67\%) years of age (Table 1). Of the metrics, data on diet were the most often missing. At 15 years of age, glucose concentrations were studied for the entire STRIP cohort for the first time. Lack of data on physical activity at 16 and 18 years of age prohibited the inclusion of these in the study. The distribution of sexes was similar between the STRIP study groups (P=0.76).

In the STRIP study, the main aim of the dietary counseling has been the replacement of saturated fat with unsaturated fat in the child’s diet (ratio of saturated to monounsaturated and polyunsaturated fatty acid of 1:2).\textsuperscript{15,16} In addition, the counseling promoted the intake of vegetables, fruits, and whole-grain products; low intake of salt; and, for example, avoidance of unnecessary changes to larger portion sizes. During the first years, the counseling was given primarily to the parents. From 7 years of age on, progressively more information was given directly to the child. The parents were carefully informed about the contents of the child’s counseling session, and they were encouraged to further discuss the same food-related topics with the child at home. The counseling was given by a nutritionist at every study visit (3- to 6-month intervals). The intervention was individualized, and the child’s recent food record was used as a basis for suggestions. A fixed diet was never ordered. Most of the counseling material was developed for the STRIP study because ready-made materials for children were sparse. Dietary recommendations were based on the Nordic nutrition recommendations.\textsuperscript{16}

Child-oriented counseling aiming at the primary prevention of smoking began at 8 years of age.\textsuperscript{2} The counseling was based on supporting the self-image of the nonsmoking children and on understanding the health risks associated with smoking. At 16.5 years of age, the detrimental effects of exposure to tobacco smoke were also discussed. A physically active lifestyle was encouraged but was not a structured, continuous part of the counseling.

The children in the control group were seen biannually until 7 years of age and annually thereafter. The control families did not routinely receive any detailed intervention focused on the prevention of atherosclerosis risk factors such as dietary fat intake or smoking.

Metrics for Ideal Cardiovascular Health

The metrics for ideal cardiovascular health in children and adolescents defined by the AHA\textsuperscript{8} were followed as precisely as possible (Table 2).

### Health Behaviors

Health behaviors included in the definition of ideal cardiovascular health were smoking habits (nonsmoking), body mass index (BMI), physical activity, and diet.\textsuperscript{2} Smoking habits were assessed with a questionnaire in which the adolescents reported how many cigarettes they had smoked during their lives. Those who reported

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>At 15 y</th>
<th>At 17 y</th>
<th>At 19 y</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Girls (n=178)</td>
<td>Boys (n=216)</td>
<td>Girls (n=189)</td>
</tr>
<tr>
<td>BMI, kg/m(^2)</td>
<td>20.7±3.1</td>
<td>20.2±3.0</td>
<td>21.6±3.4</td>
</tr>
<tr>
<td>Systolic blood pressure, mm Hg</td>
<td>115±11</td>
<td>121±13</td>
<td>113±11</td>
</tr>
<tr>
<td>Diastolic blood pressure, mm Hg</td>
<td>61±6</td>
<td>62±7</td>
<td>60±7</td>
</tr>
<tr>
<td>Total cholesterol, mmol/L</td>
<td>4.12±0.77</td>
<td>3.78±0.71</td>
<td>4.33±0.76</td>
</tr>
<tr>
<td>HDL cholesterol, mmol/L</td>
<td>1.22±0.22</td>
<td>1.08±0.22</td>
<td>1.32±0.26</td>
</tr>
<tr>
<td>LDL cholesterol, mmol/L</td>
<td>2.48±0.64</td>
<td>2.29±0.63</td>
<td>2.57±0.65</td>
</tr>
<tr>
<td>Triglycerides, mmol/L*</td>
<td>0.75 (0.49)</td>
<td>0.75 (0.49)</td>
<td>0.85 (0.49)</td>
</tr>
<tr>
<td>Insulin, µU/L*</td>
<td>7.96 (4.19)</td>
<td>7.96 (4.23)</td>
<td>7.40 (4.20)</td>
</tr>
<tr>
<td>Glucose, mmol/L</td>
<td>4.81±0.29</td>
<td>5.01±0.36</td>
<td>4.80±0.32</td>
</tr>
<tr>
<td>Leisure-time physical activity, MET h/wk</td>
<td>25.6±22.2</td>
<td>30.9±23.0</td>
<td>25.8±19.8</td>
</tr>
<tr>
<td>Never smoked a cigarette, %</td>
<td>73.5</td>
<td>65.9</td>
<td>47.7</td>
</tr>
</tbody>
</table>

BMI indicates body mass index; HDL, high-density lipoprotein; LDL, low-density lipoprotein; and MET, metabolic equivalents.

*Data are mean±SD or median (interquartile range) when appropriate.
To assess BMI, height was measured by a Harpenden stadiometer (Holtain, Crymych, Great Britain) and weight with an electronic scale (Soehnle S10; Soehnle, Murrhardt, Germany). BMI was calculated as weight in kilograms divided by height in meters squared. Adolescents who had a BMI <85th percentile were categorized as meeting the ideal cardiovascular health criteria for BMI.

Leisure-time physical activity comprising recreational and organized physical activity/sports outside school hours was assessed with a self-administered questionnaire in which the frequency, duration, and intensity of habitual leisure-time physical activity were reported. Leisure-time physical activity was calculated by multiplying the mean frequency, duration, and intensity (multiple of the resting metabolic rate; MET) of weekly leisure-time physical activity and expressed as MET hours per day. The questionnaire has been widely used in studies involving children, adolescents, and adults. It correlates moderately well with objective physical activity measures (accelerometers, r=0.26–0.40; pedometers, r=0.30–0.39) in young adults and with directly assessed maximal exercise capacity (r=0.49–0.53). Ideal physical activity level was defined as leisure-time physical activity ≥30 MET h/wk, which corresponds to >1 h/d of moderate-intensity physical activity.

Data on food consumption were assessed by use of food records kept for 4 consecutive days. During study visit, the records were reviewed by a nutritionist for completeness and accuracy. Nutrient intakes were analyzed with the Micro Nutrica program developed at the Research and Development Center of the Social Insurance Institution, Turku, Finland. The program uses the Food and Nutrient Database of the Social Insurance Institution and calculates 66 nutrients of commonly used foods and dishes in Finland. The data bank is flexible, permitting continuous updating and additions of new single or composite foods. The ideal cardiovascular health criteria for diet include the intake of fruits and vegetables, fish, fiber-rich whole grains, sodium, and sugar-sweetened beverages. The intake goals are expressed for a 2000-kcal diet and should be scaled accordingly for other levels of energy intake. Having at least 4 of the 5 dietary components is required for having an ideal diet. We followed the criteria for ideal diet as closely as possible and determined the dietary goals as follows: (1) fruits and vegetables ≥450 g/d, (2) fish ≥200 g/wk, (3) at least two 28.35-g (equal to two 1-oz) servings of whole-grain bread per day, (4) sodium ≤1500 mg/d, and (5) ≤450 kcal/wk from sugar-sweetened beverages. All intakes were scaled for energy intake to determine whether the criterion for ideal diet was met. Potatoes, juices, and jams were excluded from the intake of fruits and vegetables. Two servings were used as the minimum for whole-grain intake because only the consumption of whole-grain bread (≥5 g fiber/100 g bread) was applied.

**Health Factors**

Health factors included total cholesterol and fasting glucose concentrations and blood pressure. For the determination of total cholesterol and glucose, a fasting venous blood sample was drawn. After clotting at room temperature for 30 to 60 minutes and centrifugation at 3400g for 12 minutes, serum was separated and stored at −25°C. Blood samples used for the glucose concentration analyses were centrifuged immediately. Serum total cholesterol concentration was determined with a fully enzymatic cholesterol oxidase-p-aminophenazone method (CHOD-PAP; Merck, Darmstadt, Germany). Total cholesterol concentration was defined as ideal if <4.40 mmol/L (<170 mg/dL). Serum glucose was measured by the glucose dehydrogenase method (Merck). Glucose concentration was classified as ideal if <5.6 mmol/L (<100 mg/dL).

Seated blood pressure was measured twice with an oscillometric device (Criticon Dinamap Compact T) after 5 minutes of rest. The mean of the 2 measurements was used. Systolic and diastolic blood pressures <90th percentile were defined as ideal.

**Ideal Cardiovascular Health Score**

Using the metrics and criteria for individual ideal health factors and behaviors, we calculated the ideal cardiovascular health score corresponding to the AHA’s concept. To create the score, a value of 1 was assigned for each metric if the criterion for ideal cardiovascular health was met. If the criterion was not met, a value of 0 was assigned. The range of scores was thus 0 to 7, with a higher score indicating a better cardiovascular health profile. Additionally, a secondary ideal cardiovascular health score with modified criteria for diet was applied as previously reported by Yang and colleagues. In the diet-modified score, having at least 2 of the ideal diet components instead of 4 was required to meet the criterion of ideal diet.
Aortic IMT and Elasticity

IMT and elasticity of the abdominal aorta were studied with ultrasonography (Acuson Sequoia 512 main frame; Acuson, Mountain View, CA). The first measurements were performed at 11 years of age, and measurements were repeated every 2 years thereafter. For the aortic IMT measurements, the most distal 15 mm of the abdominal aorta was scanned with a linear-array transducer using a scanning frequency of at least 10 MHz. The image was focused on the far wall (dorsal arterial wall), and image quality was optimized with gain settings. Images 15 mm in width were magnified with a resolution box. All images were taken at end diastole, incident with the R-wave. An image of the most distal 15 mm aortic far wall was captured and was stored for subsequent offline analysis. With the use of ultrasonic calipers, 4 measurements of IMT covering the entire far wall segment were taken, and the average of these measurements was used. The interobserver coefficient of variation for the aortic IMT measurements was 3.9%, and the between-visit coefficient of variation was 4.9%.23

Elasticity of the abdominal aorta was assessed with M-mode ultrasound images and concomitant measurement of blood pressure in the brachial artery. The diameter of the aorta was measured with ultrasonic calipers twice at end diastole and twice at end systole. The means of the end-diastolic and end-systolic diameters, along with blood pressure, were used to calculate the arterial elasticity index, ie, distensibility: distensibility=(Ds−Dd)/(BPs−BPs)×1000, where Ds and Dd are the end-systolic and end-diastolic diameters of the artery and BPs and BPs are the systolic and diastolic blood pressures. Distensibility measures the ability of the arteries to expand as a response to pulse pressure caused by cardiac contraction and relaxation.22 A higher distensibility value indicates greater arterial elasticity.

Aortic IMT could be measured in 94.7% of the adolescents and elasticity in 94.8%. Of the adolescents with complete ideal cardiovascular health score, 354 (90%), 349 (93%), and 286 (96%) had aortic ultrasound measurement at 15, 17, and 19 years of age. The ultrasonography studies were performed in silence in a temperature-controlled clinical research laboratory. On the measurement day, the adolescents were advised to refrain from smoking, caffeinated drinks, juice, high-fat meals, and vitamin supplementation.

Statistical Analyses

Because of the low prevalence of adolescents with 0 or 1 of the ideal cardiovascular health metrics, adolescents with 0, 1, and 2 metrics were combined for the analyses. Low ideal cardiovascular health score was defined as having ≤3 ideal metrics. For aortic IMT and elasticity, high-risk variables were formed by the use of age- and sex-specific 85th/15th percentile cutoff points (IMT ≥85th percentile, elasticity ≤15th percentile).

Repeated measures linear regression analysis (compound symmetry covariance structure) was used to study the association of the STRIP study group and age with the ideal cardiovascular health score (adjusted for sex). Similar analyses were performed to study the association of the ideal cardiovascular health score with aortic IMT and elasticity. There was no interaction between sex and ideal cardiovascular health score when aortic IMT (P=0.71) or elasticity (P=0.36) was the outcome variable, indicating that the effect of the score on the vascular variables was similar in girls and boys. Therefore, the sexes were combined in the analyses. Linear regression analysis was performed to study the association of change in the score (score at 19 years of age minus score at 15 years of age) with change in aortic IMT (IMT at 19 years of age minus IMT at 15 years of age) and elasticity (distensibility at 19 years of age minus distensibility at 15 years of age).

The association of the STRIP study group with the risk of having low ideal cardiovascular health score was studied with a modified Poisson regression model23,24 with generalized estimating equation estimation for repeated measures (risk ratios [RRs] calculated for STRIP control versus intervention group, adjusted for age and sex). Similar analyses were used to study the association of sex and STRIP study group with the individual ideal metrics. Low ideal cardiovascular health score was also used as an explanatory variable for the outcomes high-risk IMT and elasticity (RRs calculated for low versus high score). The stability of low ideal cardiovascular health score was examined by calculating how much a low score at 15 years of age increases the RR of having a low score at 19 years of age.

Values of P<0.05 were considered significant. SAS release 9.3 (SAS Institute, Cary, NC) was used for the analyses.

Results

Ideal Cardiovascular Health in Adolescence

None of the adolescents had all 7 ideal cardiovascular health metrics (Figure 1). At least 5 ideal metrics were found in 60.2%, 45.5%, and 34.2% of the adolescents at 15, 17, and 19 years of age, respectively. The number of ideal metrics decreased with advancing age (P<0.0001; Figure 1). Of the individual metrics, the criterion for ideal diet was least often met, whereas nearly all adolescents had ideal glucose concentration (Figure 2). Between 15 and 19 years of age, the prevalence of ideal smoking decreased by 33.6% units (Figure 2). A decrease was
also found in the prevalence of ideal cholesterol (18.8% units) and ideal physical activity (9.7% units). When the components included in the criteria for ideal diet were investigated, ideal intake of whole grains was met by half of the adolescents, but practically none of them met the goal of ideal sodium intake (Table 3). Boys and girls had similar ideal cardiovascular health scores ($P=0.44$; mean±SD score: girls, 4.29±1.16; boys, 4.37±1.11). Of the individual metrics, boys more often had ideal physical activity (RR=1.20; 95% confidence interval [95% CI]=1.03–1.39; $P=0.021$) and ideal cholesterol (RR=1.45; 95% CI=1.31–1.60; $P<0.0001$), whereas girls more frequently met the criteria for ideal smoking (RR=1.17; 95% CI=1.04–1.31; $P=0.0095$), ideal blood pressure (RR=1.15; 95% CI=1.09–1.23; $P<0.0001$), and ideal glucose (RR=1.05; 95% CI=1.03–1.08; $P<0.0001$). Adolescents with a low ideal cardiovascular health score ($\leq 3$ ideal metrics) at 15 years of age had a higher risk of also having a low score at 19 years of age compared with the 15-year-old peers with a higher score (RR=1.89; 95% CI=1.13–3.14; $P=0.015$).

### Effect of Lifestyle Intervention

The risk of having a low ideal cardiovascular health score was 1.35 times higher in the control adolescents than in the intervention adolescents (RR=1.35; 95% CI=1.04–1.77; $P=0.026$). Adolescents in the intervention group also had a higher continuous ideal cardiovascular health score compared with the control adolescents when the ideal diet-modified score was used (Figure 3). When the original continuous score was applied, the difference between the study groups was not significant ($P=0.12$).

Of the individual metrics, intervention adolescents more often had ideal cholesterol (RR=1.13; 95% CI=1.03–1.24; $P=0.0076$; mean prevalence, 71.4% versus 64.2%) and blood pressure (RR=1.07; 95% CI=1.01–1.13; $P=0.019$; mean prevalence, 85.6% versus 81.0%) than the control adolescents. When the modified criterion for ideal diet was applied, intervention adolescents more often had ideal diet compared with the control adolescents (RR=1.21; 95% CI=1.02–1.44; $P=0.026$; mean prevalence, 39.0% versus 33.4%). No intervention effect was found for ideal glucose, BMI, smoking, or physical activity. Association of the intervention with the original ideal diet metric was not analyzed because of the low prevalence of those having ideal diet.

### Association of Ideal Cardiovascular Health With Aortic IMT and Elasticity

IMT of the aorta was inversely associated with ideal cardiovascular health score during adolescence (Figure 4A). The

### Table 3. Prevalence of Adolescents Having the Individual Ideal Diet Metrics

<table>
<thead>
<tr>
<th></th>
<th>Girls, %</th>
<th></th>
<th></th>
<th>Boys, %</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>At 15 y</td>
<td>At 17 y</td>
<td>At 19 y</td>
<td></td>
<td>At 15 y</td>
<td>At 17 y</td>
</tr>
<tr>
<td>Ideal fruits and vegetables</td>
<td>12.4</td>
<td>18.5</td>
<td>26.1</td>
<td>3.7</td>
<td>4.3</td>
<td>3.6</td>
</tr>
<tr>
<td>Ideal fish</td>
<td>30.9</td>
<td>36.5</td>
<td>28.7</td>
<td>28.7</td>
<td>35.3</td>
<td>29.8</td>
</tr>
<tr>
<td>Ideal whole grains*</td>
<td>54.5</td>
<td>57.7</td>
<td>58.6</td>
<td>49.5</td>
<td>47.6</td>
<td>52.5</td>
</tr>
<tr>
<td>Ideal sodium</td>
<td>0</td>
<td>0.5</td>
<td>0.6</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ideal sugar-sweetened beverage</td>
<td>27.5</td>
<td>33.9</td>
<td>31.2</td>
<td>21.8</td>
<td>22.5</td>
<td>20.6</td>
</tr>
</tbody>
</table>

*Intake of whole-grain bread used.

Figure 2. Prevalence of the individual metrics included in the ideal cardiovascular health score at 15, 17, and 19 years of age. BMI indicates body mass index.
score was also favorably associated with aortic elasticity (Figure 4B). There was no age-by-score interaction (P for IMT=0.24, P for elasticity=0.63), indicating that the effect of the ideal cardiovascular health score was similar at 15, 17, and 19 years of age. Associations of the score with IMT and elasticity were also similar in the intervention and control adolescents (study group–by–score interaction: \( P \) for IMT=0.56, \( P \) for elasticity=0.71). Change in the ideal cardiovascular health score between 15 and 19 years of age was associated with change in aortic IMT (\( \beta =-0.026; SE=0.0056; P<0.0001 \), adjusted for score and IMT at 15 years of age and sex). No association between change in the score and aortic elasticity was found (\( P=0.22 \)). The risk of having a high aortic IMT was increased in adolescents with a low ideal cardiovascular health score compared with those with a higher score (RR=1.78; 95% CI=1.31–2.43; \( P=0.0002 \), adjusted for age and sex).

**Discussion**

This study shows that ideal cardiovascular health as determined by the AHA can be promoted in adolescents. Importantly, the ideal cardiovascular health score is associated with vascular health already at this young age. Although having all 7 metrics is the ideal target, vascular health benefits are gained by the avoidance of a low ideal cardiovascular health score.

The risk of having a low ideal cardiovascular health score was reduced in the adolescents belonging to the intervention group compared with the control adolescents. There are no previous studies on the effect of lifestyle intervention on ideal cardiovascular health in children, adolescents, or adults. In terms of the behavioral components of the ideal cardiovascular health score, numerous studies have been conducted to promote a healthy lifestyle in adolescents with varying success.25–27 The unique feature of the STRIP study intervention is that it began in infancy and has been given repeatedly for 20 years. The findings of this study on reaching the individual ideal cardiovascular health metrics are in line with our prior results on risk factors and behaviors. We have previously reported a beneficial intervention effect on low-density lipoprotein cholesterol5 and blood pressure6, and, for example, clustering of overweight-related cardiometabolic risk factors,3 whereas there has been a lack of association between the study group and physical activity.17 The STRIP study intervention has focused mainly on diet; the intervention effect on having an ideal diet could not be studied because of the minimal prevalence of those achieving the ideal diet metric. When modified criteria for having an ideal diet were applied (at least 2 components required instead of 4), the intervention adolescents met the dietary goal more often compared with their control group peers. In previous studies, the intervention has favorably affected the intake of saturated fat, fiber, and vegetables.5,7,15 We suspect that the intervention effect on the individual ideal health factors is due in part to these dietary differences.

The ideal cardiovascular health score was favorably associated with vascular IMT and elasticity in adolescents. In adolescents with ≤3 ideal metrics, the risk of high aortic IMT was 1.8 times higher than in those with at least 4 of the metrics. A change in the score between 15 and 19 years of age was reflected in the change in aortic IMT; a 1-metric increase in score was associated with 0.026-mm lower change in IMT regardless of the score and IMT at 15 years of age. In line with these results, we previously showed in the Cardiovascular Risk in Young Finns cohort that a higher number of the ideal cardiovascular health metrics in childhood is associated with a reduced risk of high-risk carotid IMT in adulthood.11 In adults, the ideal cardiovascular health concept is shown to predict the incidence of CVDs12,14 and of CVD and all-cause mortality.10,13 In this cohort of adolescents, vascular IMT and elasticity were used as surrogate markers of vascular health. The results further extend the evidence of the importance of these health behaviors and factors on cardiovascular health already in adolescence. Interestingly, the effect of the score on IMT nearly plateaued after 4 ideal metrics. For elasticity, a similar phenomenon was seen after 3 of the metrics were met. In adults, a somewhat more linear, graded association between the ideal cardiovascular health score and CVD mortality
has been reported. However, in adults with at least 2 ideal metrics, the risk of cardiovascular death and the incidence of CVD are clearly reduced compared with those having 0 to 1 of the metrics. This study suggests an important public health message that one does not have to reach all 7 metrics to gain cardiovascular health benefits in adolescence; the key is to avoid having a low ideal cardiovascular health score. Consequently, the data suggest that preventive efforts could be focused on those with only a few of the ideal health behaviors or factors.

None of the adolescents had ideal cardiovascular health by the AHA definition. This was somewhat surprising considering that half of them had received repeated counseling aiming at a healthy diet and the primary prevention of smoking. In line with this finding, we recently reported a lack of reaching all 7 metrics in 12- to 18-year-old Finnish adolescents studied in 1986. Previous studies in adults have also reported a very low or nonexisting prevalence of ideal cardiovascular health. When the National Health and Nutrition Examination Survey (NHANES) 2005 to 2010 data were used, 1.2% of the adults met all 7 metrics and 8.8% of them had 0 to 1 of the ideal behaviors or factors. Similar to this study, having an ideal diet was reported as the component of the score that was least often (<1%) met. In agreement with this finding, Dong et al showed that only 0.4% of the participants had an ideal diet. The optimum level of sodium intake especially seems to be very difficult to achieve. In this longitudinal study, the ideal cardiovascular health score declined with age. Of the individual metrics, the prevalence of ideal smoking, ideal cholesterol, and ideal physical activity decreased during the follow-up. Age-related changes could not be assessed for ideal BMI and ideal blood pressure because they are defined by age-specific percentiles. The decline in the score is worrisome and reflects the increasing levels of physical inactivity during adolescence, observed also in other cohorts, and fewer adolescents reporting never having smoked with advancing age. Having a low ideal cardiovascular health score at 15 years of age was found to increase the risk of having a low score 4 years later. These data further support the early initiation of preventive efforts to promote cardiovascular health.

Limitations of this study include the use of a questionnaire to assess physical activity. Data on diet were obtained from food records, which also rely on subjective documentation and may be associated with changed eating habits during data collection or the underreporting of foods perceived as unhealthy. In the calculation of the aortic elasticity, pulse pressure measured from the brachial artery, not from aorta, was used. This is a limitation because the use of brachial pressures may overestimate pulse pressure in central arteries. However, the difference between central and peripheral pulse pressure is likely to be similar between study subjects within a narrow age range, as in the present study. Furthermore, an excellent correlation between systolic and diastolic blood pressures measured invasively from the ascending aorta and those measured noninvasively from the brachial artery has been shown. With a long follow-up period as in the STRIP study, it is inevitable that part of the original subjects discontinue participation. We have repeatedly compared those who have continued in the study with those lost to follow-up and have found no difference in, for example, saturated fat intake, weight, or total cholesterol. The most common reasons for discontinuance have been moving from the community, the child’s recurrent infections, and reluctance to blood sampling. Therefore, we do not suspect that a systematic selection bias would have influenced the observed results. Despite significant effects on quality dietary fat and serum lipid concentrations in previous studies, the overall intervention effect on the ideal cardiovascular health concept was relatively modest. One explanation could be that because of the long follow-up, those families still continuing in the study may be more health conscious and thus the control adolescents might have better cardiovascular health behaviors and factors than their peers not involved in the study. Second, the participation in a study in which information on, for example, cholesterol levels is repeatedly given may have resulted in the control group also being unintentionally intervened, making significant differences between the groups more difficult to find. The formation
of the ideal cardiovascular health score relies on the use of binary variables in which, for example, smoking a single cigarette during life is regarded the same as regularly smoking 20 cigarettes a day. This may cause that closer insight on the associations is lost. In addition, multiple testing increases the chance of false-positive findings and should be noted in the interpretation of the findings. The major strengths of the study are its unique longitudinal design with roots in infancy and the repeated, well-standardized measurement of both the metrics included in the ideal cardiovascular health score and aortic IMT and elasticity.

At present, it is clear that the process of atherosclerosis starts in childhood. This study provides novel data that cardiovascular health, according to the AHA definition, can be promoted in adolescents and is associated with surrogate markers of atherosclerosis—aortic IMT and elasticity—at this early age. These data give further support to the primordial prevention of CVDs.

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Disclosures

None.

References


The American Heart Association recently released a set of 7 cardiovascular health metrics for children and adults to describe ideal cardiovascular health. The behavioral criteria include nonsmoking, being physically active, having normal body mass index, and eating a healthy diet. Normal blood pressure, total cholesterol, and plasma glucose levels indicate ideal health factors. The prevalence of ideal cardiovascular health is very low. It is associated with cardiovascular disease incidence and with cardiovascular disease and all-cause mortality. Longitudinal data on the ideal cardiovascular health metrics are lacking, and the association of the number of ideal cardiovascular health metrics with vascular intima-media thickness and elasticity—surrogate markers of atherosclerosis—is also unknown in adolescents. In the Special Turku Coronary Risk Factor Intervention Project for Children (STRIP), repeated dietary counseling introduced in infancy and maintained until 20 years of age has led to lower intakes of saturated fat and lower serum low-density lipoprotein cholesterol levels. In this study, we examined prospectively the intervention effects on the ideal cardiovascular health concept and the association of the concept with vascular intima-media thickness and elasticity in adolescence between 15 and 19 years of age. This study shows that ideal cardiovascular health can be promoted in adolescents. Importantly, the ideal cardiovascular health score is associated with vascular health already at this young age, and although having all 7 metrics is the ideal target, vascular health benefits are gained by the avoidance of a low ideal cardiovascular health score. Clinicians should target these health behaviors and factors as part of the primordial prevention of cardiovascular diseases.
Ideal Cardiovascular Health in Adolescence: Effect of Lifestyle Intervention and Association With Vascular Intima-Media Thickness and Elasticity (The Special Turku Coronary Risk Factor Intervention Project for Children [STRIP] Study)
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