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

Running title: Laitinen et al.; Ideal Cardiovascular Health in Childhood

Tomi T. Laitinen, BM1; Katja Pahkala, PhD1,2; Costan G. Magnussen, PhD1,3; Jorma S.A. Viikari, MD, PhD4; Mervi Oikonen, PhD1; Leena Taittonen, MD, PhD5; Vera Mikkilä, PhD6; Eero Jokinen, MD, PhD7; Nina Hutri-Kähönen, MD, PhD8; Tomi Laitinen, MD, PhD9; Mika Kähönen, MD, PhD10; Terho Lehtimäki, MD, PhD11; Olli T. Raitakari, MD, PhD1,12; Markus Juonala, MD, PhD1,4

1Rsrch Ctr of Applied & Preventive Cardiovascular Med; 2Paavo Nurmi Ctr, Sports & Exercise Med Unit, University of Turku, Turku, Finland; 3Menzies Rsrch Inst, University of Tasmania, Hobart, Australia; 4Dept of Med, University of Turku & Turku University Hosp, Turku; 5Dept of Pediatrics, Vaasa Central Hospital, Vaasa & Dept of Pediatrics, University of Oulu, Oulu; 6Dept of Applied Chemistry & Microbiology, Division of Nutrition; 7Hosp for Children & Adolescents, University of Helsinki, Helsinki; 8University of Tampere & Dept of Pediatrics, Tampere University Hospital, Tampere; 9University of Eastern Finland & Dept of Clinical Physiology, Kuopio University Hosp, Kuopio; 10Dept of Clinical Physiology; 11Dept of Clin Chem, University of Tampere & Tampere University Hosp, Tampere, Finland; 12Dept of Clinical Physiology, University of Turku & Turku University Hosp, Turku, Finland

Correspondence to:
Tomi T. Laitinen, BM
Research Centre of Applied & Preventive Cardiovascular Medicine
Kiinamyllynkatu 4-8
FIN-20520 Turku, Finland.
Tel: +358-2-3130503
Fax: +358-2-3337270
E-mail: tomi.laitinen@utu.fi

Journal Subject Codes: Subject Code: [8] Epidemiology; [135] Risk Factors
Abstract:

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 to 0.85], p<0.001), metabolic syndrome (0.66 [0.52 to 0.77], p<0.001), high LDL cholesterol (0.66 [0.52 to 0.85], p=0.001), and high-risk carotid artery intima-media thickness (0.75 [0.60 to 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 in order to prevent cardiometabolic outcomes in adulthood.

Key words: cardiovascular diseases; epidemiology; risk factors; children
Introduction

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 lifestyle 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 in childhood predict the occurrence of preclinical carotid atherosclerosis in adulthood.\(^6\)\(^{-8}\)

In January 2010, the American Heart Association (AHA) released its 2020 Impact Goals where 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 whole cigarette in children, body mass index [BMI]<25 kg/m\(^2\) 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 <5.17mmol/l [<200mg/dL] in adults and <4.40mmol/l [<170 mg/dL] in children, untreated blood pressure <120mmHg/<80mmHg in adults and <90th percentile in children and untreated fasting plasma glucose <5.6 mmol/l [<100mg/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 health\(^10\) and its relationship with CVD incidence\(^11\) 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 on-going multicentre follow-up study to assess risk factors underlying CVD. The first cross-sectional survey was conducted in 1980, when 3,596 individuals aged 3-18 years participated. 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 2,204 (aged 30-45 years) of the original participants attended. For this report we chose the baseline year of 1986 since it was the first follow-up that glucose values were measured. The present sample comprised 856 participants aged 12-18 years that 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. 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. 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. In childhood, total cholesterol status was defined as ideal <4.40 mmol/l (<170mg/dL) or non-ideal ≥4.40 mmol/l (≥170mg/dL) and in adulthood as ideal <5.17 mmol/l (<200mg/dL) or non-ideal ≥5.17 mmol/l (≥200mg/dL).

Blood pressure was measured from the brachial artery using 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 [SBP] <90th percentile and diastolic blood pressure [DBP] <90th percentile) or non-ideal (SBP ≥90th percentile or DBP ≥90th percentile) and in adulthood as ideal (SBP <120 mmHg and DBP < 80 mmHg) or non-ideal (SBP ≥120 mmHg or DBP ≥ 80 mmHg).

Fasting plasma glucose (FPG) concentrations were analyzed enzymatically and classified in childhood and adulthood as ideal <5.6 mmol/l (<100mg/dL) or non-ideal ≥5.6 mmol/l (≥100mg/dL) respectively.

In the absence of a consensus pediatric MetS definition, we used the definition that we have previously shown to predict adult outcomes. Participants were categorized as having MetS if they had any three of the following five components: BMI ≥75th percentile, systolic or diastolic blood pressure ≥75th percentile, HDL-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 non-ideal ≥85th percentile and in adulthood as ideal <25 kg/m$^2$ or non-ideal ≥ 25 kg/m$^2$.

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 2-3 of these 3 ideal diet components were categorized as having an ideal childhood healthy diet score and subjects with 0-1 ideal diet components as having a non-ideal 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 fibre-rich whole grain that the AHA recommends, the questionnaire provided approximations of ideal and non-ideal 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 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 per day), ≥two 3.5 oz servings per week of fish (approximated as 1 oz per day), ≥three 1-oz servings per day of whole grains (approximated as 3 oz per day), sodium <1500 mg per day and ≤450 kcal (36 oz) of sugar-sweetened beverages per week (approximated as 5 oz per day). Subjects who had 4-5 of these 5 ideal diet components were categorized as having an ideal adult healthy diet score and subjects with 0-3 ideal diet components as having a non-ideal 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 one or more cigarettes as having a non-ideal child smoking status. In adulthood subjects were classified as current smokers (non-ideal) 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 ≥60min 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 moderate intensity or ≥ 75 min/wk vigorous intensity or ≥ 150 min/wk moderate + vigorous (approximated as ≥ 1 hour/wk vigorous intensity or ≥ 2-3 hours/wk moderate intensity or ≥ 2-3 hours/wk moderate + vigorous in the present study). Subjects that did not reach these values were
classified as having a non-ideal 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 (CV) health index corresponds to the number of ideal health factors and behaviors present at the baseline survey (1986). The ideal adult CV health index corresponds to the number of ideal health factors and behaviors present at the 2007 survey. In analyses we used the ideal CV health indices as continuous variables (index 0 to 7). Change in ideal CV health index indicates change between the ideal child and the ideal adult CV health index.

**Socioeconomic status and pack years of smoking**

Data on parental study years was assessed by a self-report questionnaire. The length of parent’s education was considered as an indicator of childhood socioeconomic status. Pack years of smoking was 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 this study. MetS was diagnosed if 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 HDL-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 mmHg, or treatment of previously diagnosed hypertension, and 5) raised FPG≥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 or greater, reported use of oral glucose-lowering medication or insulin but had not reported having type 1 diabetes, or reported a diagnosis of type 2 diabetes by a physician. Participants were classified as having hypertension if they had a SBP of 140 mmHg or greater or a DBP of 90 mmHg or greater, or if they reported use of blood-pressure lowering medication. National Cholesterol Education Project (NCEP) guidelines for low-density lipoprotein (LDL) cholesterol (4.14 mmol/l [160 mg/dL] or higher), high-density lipoprotein (HDL) cholesterol (less than 1.036 mmol/l [40 mg/dL]) and triglycerides (2.26 mmol/l [200 mg/dL]) were used to define dyslipidemia. 

**Carotid artery intima-media thickness**

Ultrasound studies were performed with Sequoia 512 ultrasound mainframes (Acuson) with 13.0-MHz linear-array transducers. Ultrasound studies were performed by trained sonographers following 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. 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 CV health factors and behaviors and serum lipids in childhood and adulthood with the ideal child CV 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 CV health index was associated with cardiometabolic outcomes in 2007, we examined age- and sex-adjusted odds ratios for the ideal child CV health index using logistic regression. To study associations of ideal child CV health index and change in ideal CV health index with carotid IMT, we used age- and sex-adjusted linear regression to calculate p-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-value <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 CV 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 from the ideal child CV health index groups 1 to 6 were observed for all ideal child health behaviors (BMI, physical activity, healthy diet score, 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 CV health index groups were observed also for adult measures of
BMI, ideal smoking status, systolic and diastolic blood pressure, total cholesterol, LDL-cholesterol and triglycerides. In addition, the ideal child CV health index was associated with the ideal adult CV health index in both unadjusted ($\beta \pm SE \ 0.37 \pm 0.05, p<0.001$) and age-and sex-adjusted ($\beta \pm SE \ 0.37 \pm 0.05, p<0.001$) linear regression models.

In childhood, the ideal CV 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 CV health index was associated with ideal adult blood pressure (OR [95% CI] 1.29 [1.12 to 1.48]), total cholesterol (1.39 [1.20 to 1.60]) and glucose status (1.29 [1.10 to 1.51]). Table 3 shows the age- and sex-adjusted odds ratios for the ideal child CV health index for prediction of cardiometabolic outcomes in adulthood with a follow-up time of 21 years. Ideal child CV health index was significantly associated with reduced odds of hypertension, metabolic syndrome, 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 non-significant. There was a linear association between ideal child CV health index and the cardiometabolic outcomes in adulthood.

**Intima-Media Thickness**

Mean adult carotid IMT among the ideal child CV health index groups are shown in Figure 1. The difference in adult carotid IMT between the ideal child CV health groups 1 and 6 was 0.067 mm. In age- and sex-adjusted linear regression models the ideal child CV health index was inversely associated with adult carotid IMT treated either as continuous (Figure 1b) or
The effect of the child ideal CV health index on adult carotid IMT remained significant ($\beta \pm SE = -0.011 \pm 0.003$, $P=0.001$) after adjusting for change in the ideal CV 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 three additional analyses. Firstly, since few participants met 1 or 6 ideal CV health metrics in childhood we combined ideal child CV health index groups 1-2 and 5-6. Secondly, 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 FPG status in childhood since the glucose values were not measured in 1980. Thirdly, we used age-and sex-specific percentiles to define ideal and non-ideal 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 non-ideal ≥80th percentile. In all 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, our 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 CV 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 \textsuperscript{6-8, 14, 19} 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 cluster of health factors and behaviors. Cardiometabolic risk factors tend to occur together more frequently than expected by chance alone\textsuperscript{5, 20, 21} and clustering of risk factors is thought to be a better measure of cardiovascular health in children.\textsuperscript{20} We have recently documented that pediatric MetS and high BMI alone predicts high carotid IMT and T2DM in adulthood.\textsuperscript{16} Few population-based studies have prospectively examined the usefulness of the childhood lipid classifications in predicting adult high-risk levels.\textsuperscript{22, 23} Also, blood pressure is shown to track from childhood to adulthood.\textsuperscript{24} 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. Bambs et al. reported a very low prevalence of ideal cardiovascular health in a middle-aged community-based study population in the U.S.\textsuperscript{10} Folsom et al. described that only 0.1\% had ideal cardiovascular health in a community-based sample in the U.S. and those who had best levels of cardiovascular health experienced relatively few events.\textsuperscript{11} Our findings are consistent with these observations even though in the present study, we have applied the AHA construct of ideal cardiovascular health to a cohort of children. None of the 856 children examined in 1986 (ages 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 min of physical activity per day have been reported in the U.S. in 12 to 19-year-olds using accelerometers.\textsuperscript{25}

Carotid IMT has been used as a surrogate marker of cardiovascular health as an alternative to the use of cardiovascular events as disease endpoints.\textsuperscript{26} Hypertension, MetS and high LDL-cholesterol are known to predict independently subsequent risk of myocardial infarction and stroke. In the study herein, participants who exhibited a high number of ideal CV 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 CV 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 have shown that carotid IMT increases 0.0057±0.0004 mm/year in healthy young adults.\textsuperscript{27} In the present study we observed a difference of 0.067mm in adult carotid IMT between ideal child CV health index groups 1 and 6. Using the vascular age concept\textsuperscript{28} this corresponds to 11.8 years meaning that participants with only 1 ideal health metric are almost 12 years older in vascular age than those with 6 metrics.

This study has limitations. Firstly, we are not currently able to study the associations with the clinical outcome of cardiovascular events. Instead, we have used carotid artery IMT and cardiometabolic outcomes as surrogate markers of cardiovascular health. Secondly, 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, which has some limitations. For example “soft drinks” included not only sugar-sweetened beverages but also diet
drinks, “fruits” included fruit juices, and fish was assessed as “fish foods”, including fish and all fish products. In addition, the intakes of sodium and fibre-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 providing an estimate of food consumption in grams per day was used. Physical activity was assessed by a subjective method both in childhood and adulthood. Thirdly, because our 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 seems to be representative of the original population. Finally, an observational study design cannot conclusively differentiate whether the observed associations between ideal child CV health index and adult outcomes are due to specific effects of youth behaviours and risk marker levels, or their life-long tracking to adulthood. The strengths of this 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 the follow-up. The ideal child CV health index was directly associated with the index in adulthood, highlighting the importance of promoting a healthy lifestyle early in life. In prior reports, we have observed that elevated LDL-cholesterol and blood pressure in youth are associated with increased intima-media thickness in adulthood, independent of adult levels. To the contrary, childhood overweight-related risks for various outcomes (hypertension, high risk IMT, dyslipidemia, type 2 diabetes) seem to be reversible among those individuals who became non-obese adults. Therefore, the quality and quantity of risk exposure in youth causing
permanent effect on adult outcomes is 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 CV health index between childhood and adulthood as a covariate in predicting carotid IMT. Both the baseline index and the change seemed 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 CV health. The findings of this study are in line with the recent recommendation of maintaining a low-risk status from childhood into young adulthood. Results from the 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 programmes targeting health behaviors and factors in childhood.

**Acknowledgements:** Biostatisticians Ville Aalto and Irina Lisinen are acknowledged for statistical advice.

**Funding Sources:** The Cardiovascular Risk in Young Finns Study was financially supported by the Academy of Finland (grants 121584, 126925, 124282, 129378), the Social Insurance Institution of Finland, the Turku University Foundation, Special Federal Grants for University Hospitals, the Juho Vainio Foundation, Paavo Nurmi Foundation, the Finnish Foundation of Cardiovascular Research, Orion-Farmos Research Foundation and the Finnish Cultural Foundation.

**Conflict of Interest Disclosures:** None.

**References:**


19. Magnussen CG, Venn A, Thomson R, Juonala M, Srinivasan SR, Viikari JS, Berenson GS, Dwyer T, Raitakari OT. The association of pediatric low- and high-density lipoprotein cholesterol dyslipidemia classifications and change in dyslipidemia status with carotid intima-media thickness in adulthood evidence from the cardiovascular risk in Young Finns study, the


### Table 1. Attrition analysis

<table>
<thead>
<tr>
<th></th>
<th>Participated in 1986 &amp; 2007</th>
<th>Participated only in 1986</th>
<th>P, unadjusted</th>
<th>P, age- and sex-adjusted</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>856</td>
<td>433</td>
<td></td>
<td></td>
</tr>
<tr>
<td>age, 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><strong>Ideal Child Health Behaviors</strong></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><strong>Ideal Child Health Factors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic BP, mmHg, 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, mmHg, 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><strong>Other Factors in Childhood</strong></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>
Table 2. Distribution of individual cardiovascular health metrics.

<table>
<thead>
<tr>
<th>Ideal Child CV Health Index, points</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(1.8%)</td>
<td>102(11.9%)</td>
<td>312(36.4%)</td>
<td>294(34.3)</td>
<td>115(13.4)</td>
<td>18(2.1)</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></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>
</tbody>
</table>

**Ideal Child Health Behaviors**

- BMI, kg/m², mean (SD): 20.1(2.9) | 25.2(3.3) | 22.4(3.3) | 20.2(2.7) | 19.4(2.4) | 19.0(2.1) | 19.3(1.8) | <0.001 |
- Ideal Physical activity, %: 6.9 | 0.0 | 1.0 | 2.2 | 6.1 | 22.6 | 38.9 | <0.001 |
- Ideal healthy diet score, %: 24.3 | 0.0 | 6.9 | 9.9 | 27.6 | 63.5 | 88.9 | <0.001 |
- Ideal smoking status, %: 22.4 | 0.0 | 8.8 | 9.9 | 28.2 | 47.0 | 83.3 | <0.001 |

**Ideal Child Health Factors**

- Systolic BP, mmHg, mean (SD): 114.1(11.5) | 126.0(14.2) | 122.6(11.8) | 113.7(11.3) | 111.9(10.9) | 111.6(8.8) | 113.6(8.7) | <0.001 |
- Diastolic BP, mmHg, mean (SD): 64.5(9.1) | 70.4(7.4) | 71.4(9.9) | 63.9(9.3) | 63.1(8.2) | 63.4(8.0) | 62.7(6.8) | <0.001 |
- Glucose, mmol/l, mean (SD): 4.7(0.8) | 5.0(0.5) | 4.8(1.1) | 4.7(0.8) | 4.7(0.8) | 4.7(0.4) | 4.8(0.3) | 0.03       |
- Total cholesterol, mmol/l, mean (SD): 4.9(0.9) | 5.5(0.6) | 5.2(0.8) | 5.1(0.9) | 4.6(1.0) | 4.4(0.9) | 4.2(0.8) | <0.001     |

**Serum Lipids in Childhood**

- LDL-cholesterol, mmol/l, mean (SD): 2.9(0.8) | 3.5(0.7) | 3.2(0.7) | 3.2(0.8) | 2.8(0.8) | 2.6(0.8) | 2.3(0.7) | <0.001 |
- HDL-cholesterol, mmol/l, mean (SD): 1.5(0.3) | 1.4(0.3) | 1.5(0.3) | 1.5(0.3) | 1.5(0.3) | 1.5(0.3) | 1.5(0.3) | 0.18       |
- Triglycerides, mmol/l, mean (SD): 0.9(0.4) | 1.5(0.8) | 1.1(0.5) | 0.9(0.4) | 0.9(0.3) | 0.8(0.3) | 0.8(0.3) | <0.001     |

**Ideal Adult CV Health Index, points**

- 3.5(1.0) | 2.4(1.7) | 3.0(1.5) | 3.4(1.5) | 3.9(1.4) | 4.0(1.4) | 4.5(1.0) | <0.001     |

**Ideal Adult Health Behaviors**

- BMI, kg/m², mean (SD): 26.0(4.7) | 31.9(6.1) | 28.4(5.6) | 26.2(4.5) | 25.1(4.2) | 25.3(4.1) | 25.2(3.5) | <0.001     |
- Ideal Physical activity, %: 51.8 | 57.1 | 50.5 | 46.6 | 54.7 | 56.1 | 72.2 | 0.05       |
- Ideal healthy diet score, %: 6.2 | 18.2 | 3.3 | 5.7 | 7.0 | 7.7 | 0.0 | 0.58       |
- Ideal smoking status, %: 74.0 | 66.7 | 67.7 | 72.3 | 74.7 | 79.1 | 88.9 | 0.01       |

**Ideal Adult Health Factors**

- Systolic BP, mmHg, mean (SD): 119.4(13.5) | 126.7(16.8) | 123.9(13.9) | 119.5(13.2) | 117.8(13.7) | 118.5(12.0) | 115.7(9.5) | <0.001     |
- Diastolic BP, mmHg, mean (SD): 74.7(11.1) | 81.8(9.9) | 78.5(11.5) | 74.0(10.7) | 74.0(11.6) | 74.2(10.4) | 71.3(7.7) | 0.001      |
- Glucose, mmol/l, mean (SD): 5.3(0.9) | 5.4(0.5) | 5.4(1.1) | 5.3(0.6) | 5.3(1.1) | 5.2(0.5) | 5.2(0.3) | 0.13       |
- Total cholesterol, mmol/l, mean (SD): 5.0(0.9) | 5.5(1.1) | 5.2(1.0) | 5.2(0.9) | 4.8(0.8) | 4.7(0.9) | 4.4(1.0) | <0.001     |

**Serum Lipids in Adulthood**

- LDL-cholesterol, mmol/l, mean (SD): 3.0(0.8) | 3.3(0.7) | 3.2(0.8) | 3.2(0.8) | 2.9(0.7) | 2.8(0.8) | 2.7(0.9) | <0.001     |
- HDL-cholesterol, mmol/l, mean (SD): 1.3(0.3) | 1.2(0.3) | 1.3(0.3) | 1.4(0.3) | 1.3(0.3) | 1.3(0.3) | 1.3(0.2) | 0.96       |
- Triglycerides, mmol/l, mean (SD): 1.4(0.8) | 2.2(1.5) | 1.6(0.9) | 1.3(0.8) | 1.3(0.8) | 1.3(0.7) | 1.0(0.3) | <0.001     |

*All child and adult CV health metrics adjusted for age and sex.*
Table 3. Age- and sex-adjusted odds ratios (OR) and 95% confidence intervals (95%CI) for AHA Ideal Child Cardiovascular Health Index for prediction of cardiometabolic outcomes in adulthood

<table>
<thead>
<tr>
<th></th>
<th>OR</th>
<th>95% CI</th>
<th>p-value</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</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><strong>High triglycerides</strong></td>
<td><strong>0.80</strong></td>
<td><strong>0.65–0.99</strong></td>
<td><strong>0.04</strong></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>

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

Figure Legend:

**Figure 1.** A. Mean values (SEM) of unadjusted adult carotid 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.
$P$ for trend = 0.003
P for trend = 0.010

Carotid IMT in Adulthood (mm)

Ideal Child Cardiovascular Health Index
Ideal Cardiovascular Health in Childhood and Cardiometabolic Outcomes in Adulthood: The Cardiovascular Risk in Young Finns Study
Tomi T. Laitinen, Katja Pahkala, Costan G. Magnusson, Jorma S.A. Viikari, Mervi Oikonen, Leena Taittonen, Vera Mikkilä, Eero Jokinen, Nina Hutri-Kähönen, Tomi Laitinen, Mika Kähönen, Terho Lehtimäki, Olli T. Raitakari and Markus Juonala

Circulation. published online March 27, 2012;
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2012 American Heart Association, Inc. All rights reserved.
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:
http://circ.ahajournals.org/content/early/2012/03/26/CIRCULATIONAHA.111.073585

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation is online at:
http://circ.ahajournals.org/subscriptions/