Childhood Nutrition in Predicting Metabolic Syndrome in Adults

The Cardiovascular Risk in Young Finns Study

Paula Jääskeläinen, bm[1]
Costan G. Magnussen, phd[1,2]
Katja Pahkala, phd[1]
Vera Mikkilä, phd[3]
Mika Kähönen, md, phd[4]
Matthew A. Sabin, md, phd[5]
Mikael Fogelholm, scd[3]
Nina Hutri-Kähönen, md, phd[6]

Leena Taittonen, md, phd[7,8]
Risto Telama, phd[9]
Tomi Laitinen, md, phd[10]
Eero Jokinen, md, phd[11]
Terho Lehtimäki, md, phd[12]
Jorma S.A. Viikari, md, phd[13]
Olli T. Raitakari, md, phd[1,14]
Markus Juonala, md, phd[1,13]

OBJECTIVE—Our aim was to study the associations of childhood lifestyle factors (the frequency of consumption of vegetables, fruit, fish, and meat, butter use on bread, and physical activity) with the metabolic syndrome (MetS) in adulthood.

RESEARCH DESIGN AND METHODS—The study cohort consisted of 2,128 individuals, 3–18 years of age at the baseline, with a follow-up time of 27 years. We used the average of lifestyle factor measurements taken in 1980, 1983, and 1986 in the analyses. Childhood dietary factors and physical activity were assessed by self-reported questionnaires, and a harmonized definition of MetS was used as the adult outcome.

RESULTS—Childhood vegetable consumption frequency was inversely associated with adult MetS (odds ratio [OR] 0.86 [95% CI 0.77–0.97], $P = 0.02$) in a multivariable analysis adjusted with age, sex, childhood metabolic risk factors (lipids, systolic blood pressure, insulin, BMI, and C-reactive protein), family history of type 2 diabetes and hypertension, and socioeconomic status. The association remained even after adjustment for adulthood vegetable consumption. Associations with the other childhood lifestyle factors were not found. Of the individual components of MetS, decreased frequency of childhood vegetable consumption predicted high blood pressure (0.88 [0.80–0.98], $P = 0.01$) and a high triglyceride value (0.88 [0.79–0.99], $P = 0.03$) after adjustment for the above-mentioned risk factors.

CONCLUSIONS—Childhood vegetable consumption frequency is inversely associated with MetS in adulthood. Our findings suggest that a higher intake of vegetables in childhood may have a protective effect on MetS in adulthood.

Diabetes Care 35:1937–1943, 2012

The metabolic syndrome (MetS) is a major medical and public health problem that has increased in prevalence during the past decades (1,2). It represents a clustering of interrelated cardiometabolic risk factors, including obesity, hypertension, dyslipidemia, hyperglycemia, and hyperinsulinemia (3,4). In adults, it is associated with the risk of cardiovascular disease and type 2 diabetes (5,6). We have previously shown that childhood obesity, high triglycerides, high insulin, high C-reactive protein (CRP), and family history of type 2 diabetes and hypertension were associated with adult MetS during the 21-year follow-up (7).

In adults, dietary patterns rich in vegetables and fruit have been associated with a decreased level of MetS (8–11). The vegetarian dietary pattern has been shown to have a beneficial effect on metabolic risk factors and to lower the risk of MetS (12). Despite this, although it is clear that MetS in adult life is influenced by lifestyle factors, especially diet and physical activity, no large-scale studies to date have investigated whether childhood nutritional factors predict adult MetS.

The aim of the current study was to examine the associations between childhood lifestyle factors (i.e., the frequency of consumption of vegetables, fruit, fish, and meat, butter use on bread, and physical activity) and MetS in adulthood. The study cohort included 2,128 individuals from the Cardiovascular Risk in Young Finns Study participating in the baseline study in 1980 (3–18 years of age) and the 27-year follow-up in 2007.

RESEARCH DESIGN AND METHODS

Subjects

The Cardiovascular Risk in Young Finns Study is a prospective follow-up study of people 3, 6, 9, 12, 15, and 18 years of age that began in 1980. At baseline, 4,320 children and adolescents were randomly selected from the Finnish national population register from the area of five university hospitals (Turku, Tampere, Helsinki, Kuopio,

and Oulu) to obtain a representative sample. In the first cross-sectional study in 1980, 3,596 of those invited participated. In the follow-up studies in 1983, 1986, and 2007, the number of participants was 2,991, 2,779, and 2,204, respectively. Subjects who were pregnant, had type 1 diabetes, or had missing covariates were excluded. Of the participants, 76 died during follow-up; two of whom died from atherosclerotic disease. A total of 2,128 individuals had sufficient data for this study. All participants gave written informed consent, and the study was approved by the local ethics committees.

Risk variables

Height and weight were measured, and BMI was calculated by dividing the subjects' weight (kilograms) by the square of their height (meters). Waist circumference was measured at the 2007 follow-up. Blood pressure was measured from the brachial artery with a standard mercury sphygmomanometer (1980 and 1983) and with a random-zero sphygmomanometer (1986 and 2007). Lipid determinations for triglycerides, total cholesterol, and HDL cholesterol were undertaken with standard methods from the venous blood samples drawn after a 12-h fast (13). LDL cholesterol was calculated with the Friedewald formula if the subject's triglyceride level was <4 mmol/L. In 2007, plasma glucose concentrations were analyzed with a clinical chemistry analyzer (AU400; Olympus), and serum insulin concentrations were measured by microparticle enzyme immunoassay kit (Abbott Laboratories Diagnostic Division, Dainabot). High-sensitivity serum CRP was analyzed by an automated analyzer (AU400; Olympus) in 2004–2005 from blood samples taken in 1980 and stored at −20°C; hence, it was only available in childhood from the 1980 study (n = 1,740) (14). Information on dietary habits, physical activity, family history of hypertension or type 2 diabetes, parents' education, smoking, and alcohol consumption was collected with questionnaires. Participants (or the parents of children 3 or 6 years of age) filled in a questionnaire on habitual dietary choices, including a 15-item food frequency questionnaire, to examine the frequency of vegetable, fruit, meat, and fish consumption, among others (15). The habitual type of bread spread consumed was also assessed, and the participants were divided into two categories: 1) those using butter or butter-based spreads and 2) all others. In the current study, we used this dietary information

collected using a nonquantitative food frequency questionnaire targeted to the total cohort. In addition, a randomly selected 50% of participants were interviewed using the 48-h recall method providing more detailed quantitative data on food consumption. As previously reported, we evaluated the validity of the dietary assessment method among this subgroup by computing the mean consumption of foods (obtained by the recall) according to the response categories of the frequency questionnaire (16). Significantly increasing consumption figures (P for trend <0.001) were found from the category "never" to "daily" in all food groups used in the current study (P for trend 0.04 for fruit; <0.001 for vegetables, meat, and butter) except fish (P for trend 0.25). In 2007, the participants completed a more comprehensive, 128-item food frequency questionnaire that provided an estimate of food consumption in grams per day (17).

Physical activity was assessed with questions concerning the frequency and intensity of physical activity, and a physical activity index was calculated based on the variables as previously described (18). There were two different kinds of questionnaires for the younger (3–6 years of age, a parent-completed questionnaire) and older children (9–18 years of age, self-completed questionnaire with the help of parents, if needed). The calculated physical activity indices were then age-standardized to ensure the data were comparative between the two groups. In addition, a subsample of subjects (n = 102) underwent maximal cycle ergometer testing; these data showed a significant correlation between physical activity index in childhood (methodology used in the present report) and exercise capacity (r = 0.39 and P = 0.03 in females; r = 0.33 and P = 0.04 in males) (19). Length of parents' education was considered an indicator of socioeconomic status. Information on smoking was collected in subjects 12–18 years of age, and those who smoked on a weekly basis or more often were considered smokers. Alcohol consumption was assessed in subjects 15–18 years of age, and those who had reported drinking beer, wine, or spirits at least once a month were considered alcohol consumers.

MetS definitions

The 2009 proposed harmonized criteria for MetS was used (20). MetS was diagnosed if the subject had at least three of the following five components: 1) waist

circumference ≥102 cm for males and ≥88 cm for females, 2) triglycerides ≥1.7 mmol/L (≥150 mg/dL) or specific treatment for this lipid abnormality, 3) HDL cholesterol <1.0 mmol/L (<40 mg/dL) in males or <1.3 mmol/L (<50 mg/dL) in females or specific treatment for this lipid abnormality, 4) blood pressure ≥130/85 mmHg or treatment of previously diagnosed hypertension, and 5) fasting plasma glucose ≥5.6 mmol/L (≥100 mg/dL) or previously diagnosed type 2 diabetes.

Statistical methods

The normality assumptions were assessed by examining histograms and normal probability plots. Values for CRP were log-transformed to render the data Gaussian in distribution. Comparisons between groups were performed using Student t test for continuous variables and Wilcoxon test for ordinal variables. To study the effects of childhood risk variables on adult MetS, we calculated the average of risk variable measurements taken in 1980, 1983, and 1986. Only the measurements conducted at 3–18 years of age were included.

The possible confounding effect of smoking and alcohol consumption was assessed separately among 12–18 year olds (n = 1,066) and 15–18 year olds (n = 771), respectively. The relationship between childhood risk variables and adult MetS (Table 2) was examined by age- and sex-adjusted logistic regression. The risk variables shown in Table 1 were entered into multivariable logistic regression analyses to evaluate the independent association of the lifestyle risk factors and traditional risk factors with adult MetS. Multivariable analyses were performed by manual stepwise modeling using backward selection. Variables were removed from the model one by one, excluding the least significant until all remaining variables were significant. We used manual-stepwise logistic regression instead of stepwise options in logistical modeling because we wanted to force age and sex into the model, as many of the investigated variables are strongly correlated with age and sex, and in the stepwise option in logistical modeling, age was dropped out of the model, although it is significant in the final model of manual-stepwise logistic regression. We also performed the analyses using the automated stepwise option with essentially similar results (data not shown). Because it is not possible to calculate ordinary R^2 in the

Table 1—*Youth characteristics in 1980 (means [SDs] or percentages [%]) and proportions of components of MetS according to adult MetS status*

	MetS status		
	No	Yes	P value
Youth characteristics in 1980			
n	1,732	396	
Age (years)	10.4 (5.0)	12.0 (4.7)	<0.0001
Male sex (%)	43.3	55.8	<0.0001
LDL cholesterol (mmol/L)	3.44 (0.81)	3.40 (0.84)	0.41
HDL cholesterol (mmol/L)	1.59 (0.31)	1.46 (0.29)	<0.0001
Triglycerides (mmol/L)	0.64 (0.28)	0.78 (0.37)	<0.0001
Systolic blood pressure (mmHg)	111 (12)	116 (12)	<0.0001
CRP (mg/L)	1.00 (3.1)	1.12 (2.8)	0.0003
Insulin (mU/L)	9.30 (5.66)	11.9 (6.89)	<0.0001
BMI (kg/m^2)	17.6 (2.8)	19.3 (3.6)	<0.0001
Physical activity index (z score)	−0.02 (0.98)	0.002 (1.03)	0.73
Fruit consumption (times/week)	7.0 (2.8)	6.4 (3.0)	0.002
Vegetable consumption (times/week)	6.3 (2.9)	5.8 (2.9)	0.001
Fish consumption (times/week)	1.1 (1.1)	1.1 (1.1)	0.22
Meat consumption (times/week)	4.9 (2.4)	4.8 (2.4)	0.55
Butter use on bread (%)	66.2	64.7	0.57
Family history of hypertension (%)	17.0	27.5	<0.0001
Family history of diabetes (%)	4.1	8.3	0.0004
Parents' education (years)	11.2 (3.8)	10.3 (3.2)	<0.0001
Proportions of components of MetS			
High plasma glucose	240 (13.9%)	228 (57.6%)	<0.0001
Large waist circumference	270 (15.6%)	295 (74.5%)	<0.0001
High blood pressure	401 (23.2%)	287 (72.5%)	<0.0001
Low HDL cholesterol	379 (21.9%)	262 (66.2%)	<0.0001
High triglycerides	181 (10.5%)	292 (73.7%)	<0.0001

P values from Student *t* test or χ^2 test.

logistic regression, R^2 are Nagelkerke pseudo-R^2 from the manual-stepwise logistic regression model, and the R^2 values indicate the increment to R^2 of the model after adding each variable into the model.

The age- and sex-adjusted relations between components of MetS and those lifestyle factors initially associated with MetS were examined by logistic regression. In the multivariable stepwise models, all childhood lifestyle and traditional risk factors shown in Table 1 were used as covariates. Odds ratios (ORs) in Tables 2 and 3 for all continuous variables represent the effect change of one SD presented in Table 1. The collinearity of variables used in the statistical analyses was examined by calculating variance inflation using linear regression analysis, and no significant collinearity was found (variance inflation <2.5). All statistical analyses were performed with SAS version 9.2. Statistical significance was inferred at a two-tailed *P* value <0.05.

RESULTS—Childhood characteristics and adult prevalence of different MetS components for those with and without adult MetS are shown in Table 1. Those with MetS had lower HDL cholesterol, were more males than females, and had higher age, triglycerides, systolic blood pressure, CRP, insulin, and BMI in childhood than those without MetS. The difference was significant for all risk variables, with the exception of LDL cholesterol. Those who had adult MetS reported having less consumption of fruit (6.4 ± 3.0 compared with 7.0 ± 2.8 times per week) and vegetables (5.8 ± 2.9 compared with 6.3 ± 2.9 times per week) than those who did not have adult MetS. There were no significant differences in physical activity index, fish consumption, meat consumption, and butter use between these two groups.

Childhood lifestyle and risk factors in predicting MetS in adulthood
Table 2 displays the age- and sex-adjusted ORs for adult MetS across childhood risk factors. Vegetable and fruit consumption frequency in childhood were inversely associated with MetS in adulthood. As there was a significant correlation between

child and adult fruit (*r* = 0.20, *P* < 0.001) and vegetable (*r* = 0.18, *P* < 0.001) consumption frequency, these analyses were repeated after additional adjustment with respective adult variables. In these, the results for childhood vegetable consumption frequency were 0.86 (95% CI 0.76–0.97), *P* = 0.01, and for childhood fruit consumption frequency were 0.89 (0.79–1.01), *P* = 0.06. Other childhood lifestyle factors were not significantly associated with adult MetS. Of the traditional risk factors, all variables were directly associated with adult MetS with the exception of HDL cholesterol and parental education, which had an inverse association. LDL cholesterol in childhood was not associated with MetS in adulthood. We also performed additional analyses using 48-h recall data available in a 50% random sample of the cohort. In this subpopulation, the age- and sex-adjusted relation of childhood total caloric intake and MetS in adulthood was nonsignificant (0.99 [0.96–1.01], *P* = 0.31). The associations of macronutrients (proteins, carbohydrates, and fat) with MetS in adulthood were examined by multivariable logistic regression analyses including age, sex, and total caloric intake as other variables. No significant association between macronutrient composition and total caloric intake in childhood and MetS in adulthood was found (data not shown).

In a multivariable stepwise analysis, the frequency of childhood vegetable consumption remained inversely associated with adult MetS (Table 3). Other significant predictors were male sex, age (inversely), BMI, HDL cholesterol (inversely), triglycerides, insulin, family history of hypertension, and family history of diabetes. Fruit consumption frequency and parental education were no longer significant after adjusting for childhood lifestyle and traditional risk factors. To further examine the effect of the frequency of fruit consumption, the multivariable analysis was also performed after exclusion of the frequency of vegetable consumption, as these variables were strongly correlated (*r* = 0.45, *P* < 0.0001). As in the primary analysis, fruit consumption frequency was not significantly associated with MetS in this model (*P* > 0.2). The association between childhood frequency of vegetable consumption and adult MetS remained significant after further adjustment with vegetable consumption in adulthood (OR 0.87 [95% CI 0.76–0.99], *P* = 0.03). To get the

Table 2—*Age- and sex-adjusted ORs and their 95% CIs for youth risk factors (years 1980–1986) in predicting adult MetS*

	OR (95% CI)	*P* value
BMI (kg/m^2)	1.95 (1.70–2.25)	<0.0001
Male sex (%)	1.69 (1.35–2.10)	<0.0001
Triglycerides (mmol/L)	1.56 (1.40–1.72)	<0.0001
Insulin (mU/L)	1.56 (1.39–1.75)	<0.0001
Age (years)	1.38 (1.23–1.54)	<0.0001
Systolic blood pressure (mmHg)	1.35 (1.18–1.54)	<0.0001
HDL cholesterol (mmol/L)	0.60 (0.53–0.68)	<0.0001
Family history of hypertension (%)	1.62 (1.24–2.10)	0.0003
CRP (mg/L)*	1.23 (1.09–1.38)	0.0008
Family history of diabetes (%)	2.08 (1.34–3.22)	0.001
Parents' education (years)	0.84 (0.74–0.95)	0.007
Vegetable consumption (times/week)	0.86 (0.77–0.96)	0.009
Fruit consumption (times/week)	0.88 (0.79–0.99)	0.03
Fish consumption (times/week)	0.95 (0.85–1.06)	0.35
LDL cholesterol (mmol/L)	1.05 (0.94–1.17)	0.39
Butter use on bread (%)	1.07 (0.827–1.39)	0.60
Physical activity index (*z* score)	0.85 (0.91–1.14)	0.78

ORs for a 1-SD increase in continuous study variables and one category change in categorical study variables. Results are sorted by *P* value. *P* values are from logistic regression analyses. *CRP was log-transformed and it was available only from the year 1980 (*n* = 1,740).

protective effect of vegetable consumption, a subject needed to eat three additional portions of vegetables per week than those without the effect. In the analysis, age had an inverse association with MetS in adulthood. The effect of childhood smoking and alcohol consumption on findings could be examined only in the older age-groups. In these analyses, the effect estimates for childhood vegetable consumption frequency predicting adult MetS remained essentially similar after adjustments for smoking and alcohol consumption (data not shown).

To study whether the relation between vegetable consumption frequency and the development of MetS differs between ages 3 and 18, we calculated sex-adjusted ORs for the frequency of childhood vegetable consumption separately for each age-group of the study population. In these analyses, ORs (95% CIs) were 0.93 (0.65–1.31) in 3 year olds, 0.88 (0.68–1.14) in 6 year olds, 0.85 (0.71–1.02) in 9 year olds, 0.80 (0.68–0.93) in 12 year olds, 0.88 (0.76–1.02) in 15 year olds, and 0.95 (0.82–1.11) in 18 year olds. No significant vegetable consumption × age interaction was observed (*P* = 0.09).

To examine the relation between youth vegetable consumption frequency and adult MetS in detail, we calculated the
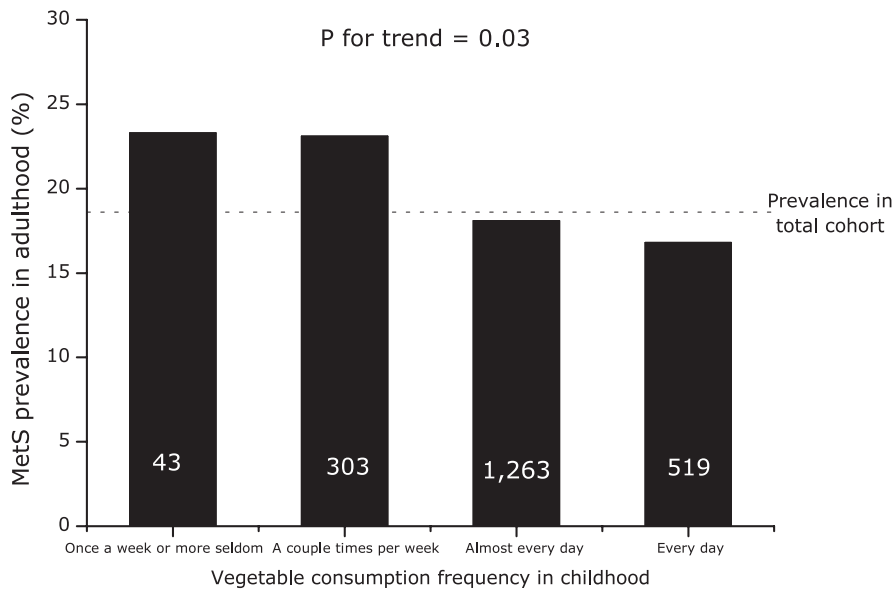
prevalence of MetS in subgroups reporting different amounts of vegetable consumption. We divided the children into subgroups as follows. The first group (*n* = 43) represents children who reported using vegetables once a week or more seldom, the second group (*n* = 303) comprised those who reported eating vegetables a couple of times per week, the third group (*n* = 1,263) included those who reported consuming vegetables almost every day, and the fourth group (*n* = 519) represents children who reported eating vegetables at least once a day. As shown in Fig. 1 there was a decreasing trend in MetS prevalence across these categories. The subjects who reported eating vegetables almost every day or every day had lower prevalence than the mean of the total cohort.

Childhood vegetable consumption frequency in predicting components of MetS

In stepwise multivariable models adjusted for all risk factors shown in Table 1, more vegetable consumption in childhood decreased the risk of high blood pressure (OR 0.88 [95% CI 0.80–0.98], *P* = 0.01) and triglyceride concentration (0.88 [0.79–0.99], *P* = 0.03) in adulthood. These associations remained significant after additional adjustments with adult vegetable consumption (*P* values 0.03 and 0.048, respectively).

CONCLUSIONS—In this study, we observed that frequent vegetable consumption in youth was associated with lower odds of adult MetS, independent of other lifestyle and traditional risk factors. Of the individual components of MetS, a low level of childhood vegetable consumption predicted high blood pressure and high triglyceride concentration. Importantly, these associations were independent of adult vegetable consumption.

Previously in this cohort, we have shown that childhood obesity, high triglycerides, high insulin, high CRP, and family history of type 2 diabetes and hypertension were determinants of adult MetS during the 21-year follow-up (7). Childhood lifestyle factors and their predictive value regarding adult MetS, however, were not studied extensively, and the follow-up period was shorter than in the present analyses. In prior studies among adults, a high vegetable consumption has been associated with a lower risk of having MetS. Rizzo et al. (12) reported in a cross-sectional analysis among 773 subjects (mean age 60 years) that a

Table 3—*Multivariable ORs and their 95% CIs for significant youth predictors of adult MetS*

	OR (95% CI)	*P* value	R^2 (%)
BMI (kg/m^2)	1.61 (1.38–1.88)	<0.0001	9.4
HDL cholesterol (mmol/L)	0.69 (0.60–0.80)	<0.0001	4.0
Male sex (%)	1.77 (1.39–2.25)	<0.0001	1.3
Triglycerides (mmol/L)	1.25 (1.11–1.40)	0.0002	1.1
Family history of hypertension (%)	1.60 (1.20–2.11)	0.001	0.8
Insulin (mU/L)	1.25 (1.10–1.42)	0.0008	0.7
Family history of diabetes (%)	1.87 (1.16–3.02)	0.01	0.5
Vegetable consumption (times/week)	0.86 (0.77–0.97)	0.02	0.3
Age in 1980 (years)	0.84 (0.72–0.98)	0.03	0.3

Data from stepwise multivariable analysis. Initial model included all variables shown in Table 1. ORs for a 1-SD increase in continuous study variables and one category change in categorical study variables. R^2 values are Nagelkerke R^2 from the manual-stepwise logistic regression model, and R^2 (%) indicate the increment to R^2 of the model after adding each variable into the model in the order shown in the table.

Figure 1—*Prevalence of adult MetS according to childhood vegetable consumption frequency. P value for a trend = 0.03. Values inside the columns indicate the number of subjects in each group.*

vegetarian dietary pattern had a favorable effect on metabolic risk factors and lowered the risk of MetS. Higher intakes of vegetables and fruit and dietary patterns rich in these foods have also been associated with a lower risk of MetS in several other studies (8–11). Our findings are in agreement with previous studies and provide novel information about the favorable influence of frequent intake of vegetables in childhood on MetS in adulthood. However, it has to be considered that when compared with well-known MetS risk factors, such as obesity, dyslipidemia, family history of diabetes, and family history of hypertension, the effect of vegetable consumption frequency was smaller. Although the effect of childhood vegetable consumption frequency on adult MetS is small, it is still important, especially as a significant association was observed with a single question.

Kouki et al. (21) have reported in the Dose Responses to Exercise Training (DR's EXTRA) study (1,334 individuals 57–78 years of age) a lower prevalence of MetS associated with higher levels of cardiorespiratory fitness and the additional benefits of a healthy diet. In their study, the impact of diet on MetS was considered weaker compared with fitness. In line with this, high physical activity has been shown to have a beneficial effect on the risk of MetS (22–25). One of these studies, Yang et al. (22), was carried out among the same cohort as the present report, but the data used in those analyses were from the years 1992–2001 and the

subjects were 24–39 years of age at the time of follow-up. In that study, subjects needed to be classified as "persistently active" to get a protective effect against MetS. However, in this study, childhood physical activity did not predict adult MetS. The effect of childhood physical activity on adult MetS may also be mediated through modification of other traditional risk factors (26) rather than due to direct effects. In multivariable analyses, age was inversely associated with MetS. However, in an analysis adjusted only with sex, increased age was related with higher MetS prevalence. These contradictory findings are most likely explained by the correlations between age and several variables within multivariable analyses.

In the 1980s, vegetables and fruit were not widely available in all seasons in Finland compared with the modern day. It is therefore possible that socioeconomic status might be a confounding factor for the present findings. However, the effect of vegetable consumption frequency remained significant in analyses taking into account parental education. On the other hand, frequent fruit and vegetable consumption at that time may thus be considered as an indicator of a purpose to choose healthy food products. The association found with more frequent childhood intake of vegetables and fruit on adult MetS may reflect the effect of overall healthy lifestyle choices related to vegetable consumption in this cohort (16). Hence our findings on the independent favorable effect of eating vegetables have

even greater relevance. Along this same line, Mozaffarian et al. (27) have recently showed the adverse effects of decreasing consumption of vegetables, among other dietary factors, on weight change in adults. We have previously shown with the Young Finns data that in univariate models, childhood vegetable consumption and fruit consumption frequency are inversely associated with carotid artery intima-media thickness progression in adulthood, and in a multivariable model, the effect of childhood fruit consumption remained significant (15). High consumption of fruit and vegetables is also part of the American Heart Association's ideal cardiovascular health goals through 2020 (28), and our results are in concert with those recommendations. The full model used in the analysis suggests that the beneficial effects of vegetable use are at least partly due to mechanisms other than improved weight control, HDL cholesterol concentration, or blood pressure. In this sense, the antioxidative and anti-inflammatory effects of vegetables, as well as functional aspects, such as low glycemic load, low energy density, and high water content, may also play a role (29).

In prior studies within this study population, we have reported that food choices (16) and physical activity (19) are established early in childhood and that these behaviors may track into adulthood. Multiple risk factors for cardiovascular diseases have also been shown to cluster already in young adults (30), and youth physical activity is associated with metabolic risk factor in youth (31). Therefore, it appears important to focus on dietary education in childhood if the prevention of the development of these adverse risk factors is to be maximized. On the basis of our results, it seems that a child should eat vegetables every day or almost every day to get the protective effect of vegetables against the MetS in adulthood. No specific age cut point was found, and childhood vegetable consumption is important at all ages.

The strength of this study was the large, randomly selected study population of young men and women who were prospectively followed-up for 27 years since childhood, but with this, there came some limitations. A potential limitation is the nonparticipation in the follow-up studies. However, we previously reported that the baseline characteristics were similar between study participants and nonparticipants (15). Therefore, the current study cohort seems to be representative of

the original population. The data on dietary variables and physical activity were gathered using questionnaires. The dietary questionnaires included only food frequency, not the number portions per day and the total energy intake per day. However, to support the validity of these methods, we have reported a significant correlation between the information obtained by the food frequency questionnaires and a 48-h dietary recall (16), and between the reported physical activity and data derived from objective measurement using accelerometry and pedometry (31) as well as maximal cycle ergometer test for fitness (19). Although we used a validated measurement for physical activity, it is possible to have inaccuracies, and that might be a possible explanation for why we did not observe a significant association between physical activity in youth and MetS in adulthood. The questionnaires were filled out by the participants among the 9–18 year olds and their parents among the 3–6 year olds. However, as no age × vegetable consumption interaction was observed, it is unlikely that this would have significantly biased the findings. The generalizability of our results is limited to white, European subjects because our study cohort was racially homogenous. Finally, these types of observational studies cannot establish causality.

In conclusion, we observed that childhood vegetable consumption frequency had a significant inverse association with adult MetS after adjustment for several lifestyle and traditional risk factors. Every effort to support a healthy lifestyle in childhood is needed to stymie the increase in the prevalence of MetS.

References
1. Ford ES, Giles WH, Mokdad AH. Increasing prevalence of the metabolic syndrome among U.S. adults. Diabetes Care 2004;27:2444–2449
2. Cameron AJ, Shaw JE, Zimmet PZ. The metabolic syndrome: prevalence in worldwide populations. Endocrinol Metab Clin North Am 2004;33:351–375
3. Reaven GM. Banting Lecture 1988. Role of insulin resistance in human disease. 1988. Nutrition 1997;13:65; discussion 64, 66
4. Gale EA. The myth of the metabolic syndrome. Diabetologia 2005;48:1679–1683
5. Wilson PW, D'Agostino RB, Parise H, Sullivan L, Meigs JB. Metabolic syndrome as a precursor of cardiovascular disease and type 2 diabetes mellitus. Circulation 2005;112:3066–3072
6. Lakka HM, Laaksonen DE, Lakka TA, et al. The metabolic syndrome and total and cardiovascular disease mortality in middle-aged men. JAMA 2002;288:2709–2716
7. Mattsson N, Rönnemaa T, Juonala M, Viikari JS, Raitakari OT. Childhood predictors of the metabolic syndrome in adulthood. The Cardiovascular Risk in Young Finns Study. Ann Med 2008;40:542–552
8. Williams DE, Prevost AT, Whichelow MJ, Cox BD, Day NE, Wareham NJ. A cross-sectional study of dietary patterns with glucose intolerance and other features of the metabolic syndrome. Br J Nutr 2000;83:257–266
9. Esposito K, Marfella R, Ciotola M, et al. Effect of a Mediterranean-style diet on endothelial dysfunction and markers of vascular inflammation in the metabolic syndrome: a randomized trial. JAMA 2004;292:1440–1446
10. Esmaillzadeh A, Kimiagar M, Mehrabi Y, Azadbakht L, Hu FB, Willett WC. Fruit and vegetable intakes, C-reactive protein, and the metabolic syndrome. Am J Clin Nutr 2006;84:1489–1497
11. Babio N, Bulló M, Salas-Salvadó J. Mediterranean diet and metabolic syndrome: the evidence. Public Health Nutr 2009;12:1607–1617
12. Rizzo NS, Sabaté J, Jaceldo-Siegl K, Fraser GE. Vegetarian dietary patterns are associated with a lower risk of metabolic syndrome: the Adventist Health Study 2. Diabetes Care 2011;34:1225–1227
13. Raitakari OT, Juonala M, Rönnemaa T, et al. Cohort profile: the Cardiovascular Risk in Young Finns Study. Int J Epidemiol 2008;37:1220–1226
14. Juonala M, Viikari JS, Rönnemaa T, Taittonen L, Marniemi J, Raitakari OT. Childhood C-reactive protein in predicting CRP and carotid intima-media thickness in adulthood: the Cardiovascular Risk in Young Finns Study. Arterioscler Thromb Vasc Biol 2006;26:1883–1888
15. Juonala M, Viikari JS, Kähönen M, et al. Life-time risk factors and progression of carotid atherosclerosis in young adults: the Cardiovascular Risk in Young Finns study. Eur Heart J 2010;31:1745–1751
16. Mikkilä V, Räsänen L, Raitakari OT, Pietinen P, Viikari J. Consistent dietary patterns identified from childhood to adulthood: the Cardiovascular Risk in Young Finns Study. Br J Nutr 2005;93:923–931
17. Koskinen J, Magnussen CG, Taittonen L, et al. Arterial structure and function after recovery from the metabolic syndrome: the Cardiovascular Risk in Young Finns Study. Circulation 2010;121:392–400
18. Telama R, Viikari J, Välimäki I, et al. Atherosclerosis precursors in Finnish children and adolescents. X. Leisure-time physical activity. Acta Paediatr Scand Suppl 1985;318:169–180
19. Telama R, Yang X, Viikari J, Välimäki I, Wanne O, Raitakari O. Physical activity from childhood to adulthood: a 21-year tracking study. Am J Prev Med 2005;28:267–273
20. Alberti KG, Eckel RH, Grundy SM, et al.; International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; International Association for the Study of Obesity. Harmonizing the metabolic syndrome: a joint interim statement of the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; and International Association for the Study of Obesity. Circulation 2009;120:1640–1645
21. Kouki R, Schwab U, Lakka TA, et al. Diet, fitness and metabolic syndrome - The DR's EXTRA Study. Nutr Metab Cardiovasc Dis. 24 December 2010 [Epub ahead of print]
22. Yang X, Telama R, Hirvensalo M, Mattsson N, Viikari JS, Raitakari OT. The longitudinal effects of physical activity

history on metabolic syndrome. Med Sci Sports Exerc 2008;40:1424–1431

23. Ford ES, Li C. Physical activity or fitness and the metabolic syndrome. Expert Rev Cardiovasc Ther 2006;4:897–915

24. Laaksonen DE, Lakka HM, Salonen JT, Niskanen LK, Rauramaa R, Lakka TA. Low levels of leisure-time physical activity and cardiorespiratory fitness predict development of the metabolic syndrome. Diabetes Care 2002;25:1612–1618

25. Eisenmann JC. Aerobic fitness, fatness and the metabolic syndrome in children and adolescents. Acta Paediatr 2007;96:1723–1729

26. Raitakari OT, Taimela S, Porkka KV, et al. Associations between physical activity and risk factors for coronary heart disease: the Cardiovascular Risk in Young Finns Study. Med Sci Sports Exerc 1997;29:1055–1061

27. Mozaffarian D, Hao T, Rimm EB, Willett WC, Hu FB. Changes in diet and lifestyle and long-term weight gain in women and men. N Engl J Med 2011;364:2392–2404

28. Lloyd-Jones DM, Hong Y, Labarthe D, et al.; American Heart Association Strategic Planning Task Force and Statistics Committee. Defining and setting national goals for cardiovascular health promotion and disease reduction: the American Heart Association's Strategic Impact Goal through 2020 and beyond. Circulation 2010;121:586–613

29. Bazzano LA, Serdula MK, Liu S. Dietary intake of fruits and vegetables and risk of cardiovascular disease. Curr Atheroscler Rep 2003;5:492–499

30. Raitakari OT, Leino M, Räkkönen K, et al. Clustering of risk habits in young adults. The Cardiovascular Risk in Young Finns Study. Am J Epidemiol 1995;142:36–44

31. Mansikkaniemi K, Juonala M, Taimela S, et al. Cross-sectional associations between physical activity and selected coronary heart disease risk factors in young adults. The Cardiovascular Risk in Young Finns Study. Ann Med. 1 July 2011 [Epub ahead of print]