

Ideal Cardiovascular Health and Adiposity: Implications in Youth

Amber L. Fyfe-Johnson, ND, PhD; Justin R. Ryder, PhD; Alvaro Alonso, MD, PhD; Richard F. MacLehose, PhD; Kyle D. Rudser, PhD; Claudia K. Fox, MD; Amy C. Gross, PhD; Aaron S. Kelly, PhD

Background—The American Heart Association set 2020 Strategic Impact Goals that defined cardiovascular risk factors to be included in the concept of ideal cardiovascular health (ICH). The prevalence of ICH among differing levels of adiposity in youth, especially severe obesity, is uncertain.

Methods and Results—The cross-sectional study measured ICH metrics in 300 children and adolescents stratified by adiposity: normal weight, overweight/obese, and severely obese. ICH incorporates 7 behavioral and health metrics, and was characterized as poor, intermediate, or ideal. Individual ICH metrics were transformed into standardized sample z-scores; a summary ICH sample z-score was also calculated. Multivariable linear regression models were used to estimate differences in ICH sample z-scores by adiposity status. Of the 300 participants, 113 were classified as having normal weight, 87 as having overweight/obesity, and 100 as having severe obesity (mean age 12.8 years, SD 2.7; 48% female). No participants met the criteria for ICH; 80% of those classified as having normal weight, 81% of those with overweight/obesity, and all of those with severe obesity were in poor cardiovascular health. After multivariable adjustment, those with overweight/obesity (sample z-score: -1.35 ; 95% confidence interval, $-2.3, -1.1$) and severe obesity (sample z-score: -1.45 ; 95% confidence interval, $-2.9, -0.92$) had lower overall ICH sample z-scores compared with participants with normal weight. Results were similar for individual ICH metrics.

Conclusions—Poor cardiovascular health was highly prevalent in youth; ICH sample z-scores increased across levels of adiposity. Youth with obesity, particularly those with severe obesity, remain a rich target for primary prevention efforts.

Clinical Trial Registration—URL: <http://www.clinicaltrials.gov>. Unique identifier: NCT01508598. (*J Am Heart Assoc.* 2018;7:e007467. DOI: 10.1161/JAHA.117.007467.)

Key Words: adolescence • ideal cardiovascular health • obesity • pediatrics • risk factor

To a great extent, cardiovascular disease is preventable; individuals without cardiovascular risk factors have low rates of cardiovascular disease in adulthood.^{1,2} In an attempt to prioritize cardiovascular health and shift towards primordial prevention, the American Heart Association (AHA) set 2020 Strategic Goals that included the concept of ideal cardiovascular health (ICH).³ ICH incorporates 7 health metrics (smoking, body mass index [BMI], physical activity, diet,

blood pressure, total cholesterol, and glucose), and is characterized as poor, intermediate, or ideal based on the number of metrics an individual meets. ICH is defined as meeting the ideal definition for all 7 metrics. The Cardiovascular Risk in Young Finns Study reported a relationship between low ICH (below the median number of “ideal” metrics) in childhood with cardiovascular disease in adulthood. A noteworthy finding was that no children in this study met all 7 metrics for ICH.^{4,5} In the same cohort, individuals who changed their ICH status from low to high from childhood to adulthood had similar cardiometabolic health profiles as the participants originally classified as having high ICH as children.⁶

Excess adiposity remains a serious public health threat^{7,8}; 33% of US adolescents are classified as having overweight or obesity.^{7,9} Despite a potential plateau in overall obesity rates, the prevalence of severe obesity in children and adolescents 2 to 19 years of age has increased from 4% in 1999 to 2004,¹⁰ to >8% in 2013 to 2014.⁷ Severe obesity in youth is associated with increased cardiometabolic risk factors,¹¹ vascular dysfunction,¹² increased oxidative stress,¹³ and risk

From the Division of Epidemiology and Community Health (A.L.F.-J., R.F.M.), and Biostatistics (K.D.R.), School of Public Health, University of Minnesota, Minneapolis, MN; College of Medicine, Washington State University, Seattle, WA (A.L.F.-J.); Department of Pediatrics (J.R.R., A.C.G., A.S.K.), and Medicine (C.K.F., A.S.K.), University of Minnesota Medical School, Minneapolis, MN; Rollins School of Public Health, Emory University, Atlanta, GA (A.A.).

Correspondence to: Amber L. Fyfe-Johnson, PhD, ND, 1100 Olive Way, Suite 1200, Seattle, WA 98101. E-mail: afj@wsu.edu

Received September 13, 2017; accepted March 6, 2018.

© 2018 The Authors. Published on behalf of the American Heart Association, Inc., by Wiley. This is an open access article under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made.

Clinical Perspective

What Is New?

- In a pediatric cohort study that included severely obese children and adolescents, no participants were in ideal cardiovascular health (ICH) and the prevalence of poor ICH was high in both the normal weight and overweight/obese groups.
- Overall sample z-scores for a continuous ICH metric suggest that individuals with normal weight, on average, have a higher continuous ICH sample z-score than those with overweight or obesity.
- Children who qualified for free or reduced-price school lunch had lower cardiovascular health than individuals in more stable financial situations.

What Are the Clinical Implications?

- Clinicians are in a unique position to recommend behavioral changes to patients and families at all levels of adiposity, with particular consideration given to those in situations of financial hardship.
- Because poor ICH was found in all adiposity categories, population-level interventions such as developing school-based policy changes or programs could be beneficial.
- If generated using a nationally representative data source, modifying ICH to a continuous metric could further enhance its ability to stratify cardiovascular risk in childhood and adolescence.

factors for chronic disease.¹⁴ Recent evidence suggests that cardiovascular mortality in adulthood was 3.5 times higher (95% confidence interval, 2.9–4.1) for individuals classified as having obesity as adolescents. The AHA estimates that 33% of adolescents do not meet the ICH metric for ideal BMI (ie, were classified as having overweight or obesity).¹⁵ Given the prevalence of overweight and obesity in children, considerable attention has been paid to the role of adiposity as a precursor to the development of adult cardiovascular disease.^{16–18} Mendelian randomization studies confirm that adiposity is a causal risk factor for cardiovascular risk factors and atherosclerosis in adulthood.^{19,20} Therefore, identifying children based on adiposity who are at risk for clinically evident cardiovascular disease later in life may be an important strategy for cardiovascular disease prevention.^{18,21}

Given that pediatric cohort studies report an absence of ICH in children^{4,22} and secular trends show increases in severe obesity prevalence,¹⁴ the clinical utility of the ICH metric could be improved with a greater focus on adiposity status. Furthermore, it is unclear whether categorizing biologically continuous risk factors for ICH estimation is the ideal approach.^{23,24} To our knowledge, no data exist on the prevalence of ICH across levels of adiposity in a pediatric

population, nor has an adiposity-specific or continuous ICH metric been proposed. The objectives of the current study were 2-fold. First, we aimed to improve the understanding of the distribution of ICH metrics by adiposity status. Second, we examined the same ICH metrics by adiposity status using a continuous ICH sample z-score.

Methods

The data, analytic methods, and study materials will not be made available to other researchers for purposes of reproducing the results or replicating the procedure.

Study Population

This cross-sectional study included 300 children and adolescents aged 8 to 17 years from the greater Minneapolis and St. Paul metropolitan area recruited from 2011 to 2016. Enrollment was stratified by adiposity: normal weight, overweight/obese, and severely obese. Participants were recruited from various pediatric clinics, including the University of Minnesota Masonic Children's Hospital Pediatric Weight Management Clinic (participants with obesity or severe obesity only). Participants and parents provided assent and written informed consent, respectively. The study protocol was approved by the University of Minnesota Institutional Review Board.

Participants were excluded if they met any of the following criteria: (1) untreated obstructive sleep apnea (known to impact endothelial function); (2) genetic causes of obesity (ie, Prader-Willi); (3) previous medical history of weight loss surgery; (4) current medications known to affect the endothelium (ie, statins, angiotensin-converting enzyme inhibitors, peroxisome-proliferator-activated receptor- γ agonists, metformin, and third-generation β -blockers); (5) current use of stimulants for attention deficit and hyperactivity disorder (eg, methylphenidate), illness, hospitalization, or trauma in the previous 2 weeks, type I diabetes mellitus, familial hypercholesterolemia, chronic kidney disease or end-stage renal disease, Kawasaki disease (inflammatory disease of the vasculature), autoimmune inflammatory disease, or congenital heart disease.

ICH Metrics

In 2010, the AHA established the ICH metric.³ Seven health metrics have been established to define cardiovascular health—categorized as poor, intermediate, or ideal (Table 1, as seen in the Introduction). ICH is defined as meeting all 7 cardiovascular health metrics and the absence of cardiovascular disease or cardiovascular medication use. The 7 cardiovascular health metrics are split into 4 health behaviors (smoking status, physical activity, dietary patterns, and BMI)

Table 1. Definitions of Poor, Intermediate, and Ideal Cardiovascular Health According to AHA 2020 Goals: Health Behaviors and Risk Factors for Children 12 to 19 Years of Age*

Metric	Poor	Intermediate	Ideal
Smoking status	Tried >30 d ago	...	Never tried; never smoked whole cigarette
BMI	>95th percentile	85th–95th percentile	<85th percentile
Physical activity level	None	>0 and <60 min of moderate or vigorous every d	≥60 min of moderate or vigorous every d
Healthy diet score [†]	0–1 components	2–3 components	4–5 components
Total cholesterol	≥200 mg/dL	≥170–<200 mg/dL	<170 mg/dL
Blood pressure	>95th percentile	90–95th percentile	<90th percentile
Fasting blood glucose	≥126 mg/dL	100–125 mg/dL	<100 mg/dL

AHA indicates American Heart Association; BMI, body mass index; DBP, diastolic blood pressure; ellipses (...), data not available; PA, physical activity; SBP, systolic blood pressure.

*Reprinted with permission from Lloyd-Jones et al; *Circulation*. 2016;121:586–613.³ © 2016 American Heart Association, Inc.

[†]The Healthy Diet Score is based on adherence to the following dietary recommendations: fruits and vegetables, ≥4.5 cups/d; fish, 2 or more 3.5-oz servings/wk; sodium, <1500 mg/d; sugar-sweetened beverages, ≤450 kcal (36 oz) per wk; and whole grains, ≥3 servings/d scaled to a 2000-kcal/d diet.

and 3 health factors (fasting total cholesterol, blood glucose, and blood pressure). Table 1 details specific definitions of poor, intermediate, and ideal cardiovascular health for children aged 12 to 19 years.

Clinical ideal cardiovascular components: BMI, blood pressure, total cholesterol, and glucose

Height was measured using a wall-mounted stadiometer; weight was measured using a medical-grade electronic scale. BMI was calculated and reported in kilograms per meter squared (kg/m^2). Centers for Disease Control and Prevention definitions of sex- and age-based BMI percentiles (2–20 years of age) were used.²⁵ Study BMI categories were defined as the following: normal weight: BMI <85th percentile; overweight/obese: BMI 85th percentile to <1.2 times the 95th percentile, and severely obese: BMI ≥1.2 times the 95th percentile or BMI ≥35 kg/m^2 .¹⁴ Seated blood pressures were taken using a manual sphygmomanometer, using an appropriately fitted cuff. Each participant sat quietly with legs uncrossed for 10 minutes before blood pressure measurement. Three consecutive blood pressure readings were taken at least 3 minutes apart. The average of the final 2 measurements was used. Fasting blood samples (>10 hours) were collected and total cholesterol, low-density lipoprotein cholesterol, high-density lipoprotein cholesterol, triglycerides, glucose, and insulin were measured using standard methods by the Fairview Diagnostics Laboratories, Fairview-University Medical Center (Minneapolis, MN)—a Center for Disease Control and Prevention certified laboratory.

Lifestyle ICH components: diet, physical activity, and smoking exposure

Dietary intake was measured using the Youth/Adolescent Questionnaire (YAQ), a semiquantitative food frequency questionnaire. The YAQ asks participants about dietary and

supplement intake in the previous year.^{26,27} General physical activity was assessed using a modified Godin Leisure-Time questionnaire^{28,29} that assessed (1) intensity (strenuous, moderate, mild) of physical activity in the previous week during free time, (2) participation in organized sports in the previous years, and (3) leisure time physical activity (at least 10 times in the previous year). Smoking exposure was evaluated by self-report questionnaire as never, current, former, previous, or secondhand smoke exposure.

Conversion from study instruments to ICH components

BMI categorization and total cholesterol, blood pressure, and glucose thresholds were consistent between the study instruments and ICH guidelines; therefore, no modifications were made to these variables. Current (n=2) and former smokers (n=5) were categorized as meeting the definition of poor ICH, whereas never smokers (n=293) were classified as meeting ICH. The modified Godin Leisure-Time questionnaire assessed strenuous and moderate physical activity in the past week (times per week and minutes per session). Strenuous and moderate activity was defined as “heart beats rapidly” and “not exhausting,” respectively; both listed various activities that were relevant. For the ICH metric, we calculated minutes per day of moderate and vigorous physical activity using the following equation: (times per week × minutes per session)/7 days per week. The YAQ is a 152-item food frequency questionnaire that collects a comprehensive assessment of food intake in the past week or month. We utilized 45 questions that met the specified Dietary Approaches to Stop Hypertension (DASH) food categories for the ICH guidelines: fruits/vegetables (n=30), whole grains (n=10), fish (n=2), sugar-sweetened beverages (n=3), and salt intake (micronutrient analysis). Nearly all food questions assessed frequency of intake using the following, or similar, answer options: (1) never/less than 1 per month, (2) 1 to 3

per month, (3) 1 per week, (4) 2 to 4 times per week, and (5) 5 times per week. We calculated frequency of intake by taking the midpoint (ie, midpoint=2 servings per month if participant chose option #2 [1–3 per month]) or absolute value (ie, serving=1 if participant chose option #3 [1 per week]) reported. We then calculated the total servings per unit of time for each relevant ICH dietary subcomponent: fruits and vegetables (≥ 4.5 cups/d), whole grains (≥ 3 servings/d), fish (\geq two 3.5-oz servings/wk), sugar-sweetened beverages (≤ 36 oz/wk), and salt (≤ 1500 mg/d) based on a 2000-kcal/d diet. For example, for fruit and vegetable consumption, each participant's overall servings per day were a summary score of servings from the relevant 30 fruit/vegetable YAQ questions. This process was repeated for whole grains, fish, and sugar-sweetened beverages. A summary salt intake was calculated using a proprietary micronutrient algorithm at the Harvard T.H. Chan School of Public Health Nutrition Department.

Sociodemographics

Age and race were determined based on self-report; race was categorized as non-Hispanic white and black. Socioeconomic status was approximated by self-report of free or reduced-price lunch eligibility. Sex and pubertal stage were determined by a pediatrician or trained nurse using classical Tanner staging.³⁰

Exclusions and Missing Data

Of the 309 participants, we excluded individuals for the following reasons: (1) no Tanner stage performed ($n=5$), and (2) participant declined venipuncture, unable to perform a successful venipuncture, or nonfasting ($n=4$). Our final sample size was 300 observations. Additional individuals would have been excluded based on missing dietary intake ($n=154$; new instrument version released midstudy, data unable to be processed off-site because of old versioning), physical activity ($n=30$), and eligibility for free or reduced-price lunch ($n=183$; collection began midstudy). To minimize selection bias, maximize the use of available information, and capture appropriate uncertainty estimates, we used multiple imputation by chained equations with 25 repetitions to impute missing data for these individuals who would have been excluded in a complete case analysis based on missing data.³¹ Because both dietary intake and eligibility for free lunch were dependent on chronological time of measurement, we operated under the assumption that the missingness mechanism was missing at random. Results between the complete case analysis and nonimputed data set were similar; we opted to use the imputed data set based on the aforementioned strengths of multiple imputation by chained equations.

Statistical Analysis

Baseline characteristics of participants are described using means (SD) and frequency (percentages) stratified by categories of adiposity (normal weight, overweight/obese, and severely obese). For the first study objective, prevalence of overall ICH and ICH subcomponents were calculated across levels of adiposity. For the second study objective, a continuous ICH z-score was generated, both as an overall ICH score and ICH subcomponent scores. The overall ICH score was calculated based on the average of the individual z-scores (standardized to the sample mean and SD) of the ICH subcomponents (BMI, physical activity, healthy diet score, total cholesterol, blood pressure, and glucose). BMI was converted to age and sex-standardized scores using Centers for Disease Control and Prevention growth charts.^{32,33} For overall blood pressure and healthy dietary consumption z-scores, an average of the individual z-scores (systolic blood pressure and diastolic blood pressure percentiles for blood pressure; fruits and vegetables, whole grains, fish, sugar-sweetened beverages, and sodium intake for diet) was used to calculate the overall z-score. To maintain consistency in sample ICH z-score interpretation (higher is better), all risk factors conferring cardiovascular risk were multiplied by -1 to flip the direction of the score (eg, higher blood pressures have negative values to contribute to a lower overall ICH z-score). The z-score represents the number of SDs a measurement is from the mean, and allows comparison between variables measured on different scales, from different distributions. A z-score greater, equal to, or less than 0 estimates that a particular variable is greater than, equal to, or less than the mean, respectively.^{34,35} For our final study objective, multiple linear regression models were used to estimate differences in ICH z-scores by adiposity status after adjustment for demographics and Tanner stage (Model 1), and additional adjustment for reduced-price or free lunch eligibility (Model 2). Smoking was not included in our primary analysis because only 2 participants were current smokers, and 5 were former smokers. All analyses were performed using Stata 14 and *R* software packages.^{36,37}

Results

Table 2 shows descriptive statistics for baseline variables presented separately by adiposity level (normal weight, overweight/obese, and severely obese). In general, participants with severe obesity were more likely to be female, nonwhite, have a higher Tanner stage of pubertal development, be eligible for reduced-price or free lunch, and be above the 90th SBP percentile. Individuals with severe obesity also had higher mean insulin, low-density lipoprotein cholesterol, total cholesterol, and triglyceride levels than their

Table 2. Baseline Characteristics by Adiposity Status (N=300)

	Adiposity Status		
	NW	OW/OB	SO
N	113	87	100
BMI, kg/m ² (SD)	18.4 (2.4)	26.5 (3.5)	35.9 (6.1)
BMI, percentile (SD)*	73.6 (6.7)	106.0 (10.0)	140.1 (16.8)
Total tissue fat, N (%)	25.2 (6.1)	39.5 (7.2)	48.1 (4.9)
Visceral fat mass, g (SD)	74 (54.0)	412.5 (275)	1097 (585)
Demographics			
Age, y (SD)	12.5 (2.5)	12.5 (2.5)	13.1 (2.7)
Male, N (%)	68 (58)	43 (48)	38 (38)
Race, N (%)			
White	109 (93)	74 (83)	77 (76)
Other	8 (7)	15 (17)	24 (24)
Tanner stage, N (%)			
1	45 (39)	23 (27)	16 (16)
2	20 (17)	18 (21)	26 (26)
3	17 (15)	18 (21)	18 (18)
4	22 (19)	15 (17)	22 (22)
5	11 (10)	12 (14)	17 (17)
Free or reduced-price lunch eligibility, N (%)	17 (15)	16 (18)	34 (34)
Clinical variables			
Weight, kg (SD)	44.3 (13.1)	65.9 (16.8)	93.8 (26.5)
Height, cm (SD)	153.2 (15.1)	156.3 (13.7)	159.8 (12.5)
WC, cm (SD)	63.2 (6.9)	80.5 (9.5)	100.0 (14.6)
SBP, mm Hg (SD)	107 (11)	116 (11)	124 (12)
SBP ≥90th percentile, N (%)	4 (3)	18 (20)	51 (50)
DBP, mm Hg (SD)	54 (7)	58 (9)	61 (8)
DBP ≥90th percentile, N (%)	1 (1)	3 (3)	3 (3)
Insulin, mU/L (SD)	4 (3)	10 (6)	17 (11)
Glucose, mg/dL (SD)	78 (9)	81 (9)	80 (8)
LDL-c, mg/dL (SD)	81 (24)	95 (24)	97 (28)
HDL-c, mg/dL (SD)	57 (12)	47 (12)	41 (9)
Total cholesterol, mg/dL (SD)	153 (27)	165 (27)	164 (31)
TG, mg/dL (SD)	71 (27)	113 (56)	133 (50)

Percentages may not add up to 100% based on rounded estimates. BMI indicates body mass index; CDC, Centers for Disease Control and Prevention; DBP, diastolic blood pressure; HDL-c, high-density lipoprotein cholesterol; LDL-c, low-density lipoprotein cholesterol; NW, normal weight; OB, obese; OW, overweight; SBP, systolic blood pressure; SO, severely obese; TG, triglycerides; WC, waist circumference.

*Age- and sex-adjusted percentiles based on CDC criteria used to account for pubertal development during adolescence.

normal-weight counterparts. Conversely, high-density lipoprotein cholesterol was lower in participants with severe obesity. Of the 300 participants included in our analysis, none met the

AHA definition of ICH (Table 2). When examining the prevalence of ICH components by adiposity status (Table 2), very few participants were current smokers (n=2) or had elevated glucose levels (n=7). Only 1 participant met the criteria for ideal healthy diet score. Participants with severe obesity were more likely to fall in the “poor” ICH category for physical activity level (16% versus 1%), total cholesterol (16% versus 4%), and blood pressure (30% versus 1%). For overall ICH, all participants with severe obesity were in poor cardiovascular health; most of the participants with overweight/obesity (81%) and normal weight (80%) were also in poor cardiovascular health. The total number of ICH components increased with healthier adiposity status; 58% of normal-weight participants met the definition of 5 ICH components, whereas only 2% of individuals with severe obesity met the same criteria (Figure).

For all results reporting continuous z-scores, a positive value indicates higher ICH sample z-score; a negative value represents a lower ICH sample z-score. Normal-weight participants had a higher overall ICH sample z-score (0.80 ± 0.9) than participants with overweight/obesity (-0.40 ± 0.7) and severe obesity (-0.58 ± 0.8) (Table 3). Sample z-scores for physical activity, systolic blood pressure percentile, diastolic blood pressure percentile, overall blood pressure percentile, and glucose were all in the positive range for normal-weight participants, and negative for participants with overweight/obesity and severe obesity. The overall healthy diet consumption z-score followed a similar pattern, but participants with overweight/obesity had positive sub-component z-score values for fruits and vegetable, fish, and sodium (0.03 ± 0.9 , 0.16 ± 1.1 , and 0.07 ± 1.1 , respectively). More specifically, only 4%, 9%, and 2% of participants with normal weight, overweight/obesity, and severe obesity consumed the ICH recommended ≥ 2 servings of fish per week (Table 4). Few participants met the ICH sodium intake recommendations of ≤ 1500 mg sodium daily: 6%, 9%, and 23% for participants with normal weight, overweight/obesity, and severe obesity, respectively. Ideal fruit and vegetable consumption (≥ 4.5 servings daily) was relatively consistent across all adiposity levels; ideal whole grain intake was higher in participants with normal weight (48%) compared with overweight/obesity (30%) and severe obesity (18%). Ideal levels of sugar-sweetened beverages (≤ 36 oz weekly) were most prevalent: 63%, 72%, and 56% in participants with normal weight, overweight/obesity, and severe obesity, respectively (Table 5). In a multiple linear regression model adjusting for demographics and eligibility for free or reduced-price lunch, compared with normal weight, the ICH z-score was lower for participants with overweight/obesity (-1.35 ; 95% confidence interval, -2.3 , -1.1) and severe obesity (-1.45 ; 95% confidence interval, -2.9 , -0.92) (Table 6). No differences in results were present when stratifying by sex or race/ethnicity. Results were similar for individual ICH metrics.

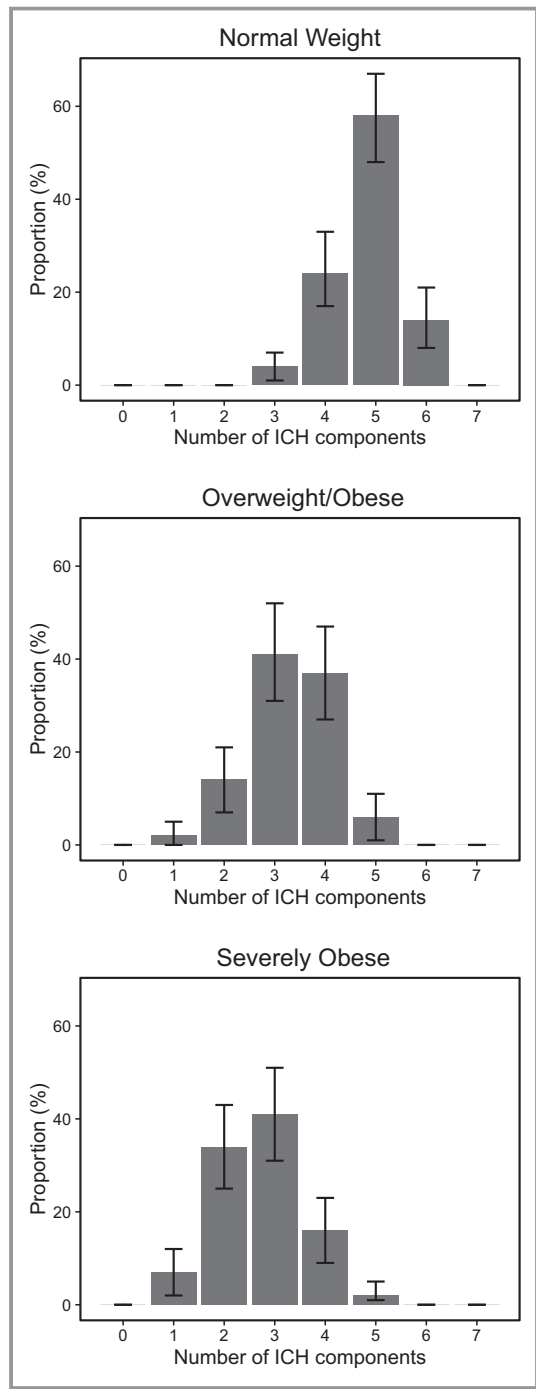


Figure. Prevalence of number of ideal cardiovascular health (ICH) subcomponents* by adiposity status (n=300). *Those in the OW/OB and SO categories unable to attain 7 ICH components based on adiposity status. Error bars indicate the 95% confidence interval that would be anticipated in the population given the data. OB indicates obese; OW, overweight; SO, severely obese.

Discussion

In this study, we used the AHA’s “Strategic Impact Goal Through 2020 and Beyond”³ ICH metric to examine the

Table 3. ICH Components by Adiposity Status (N=300)

	Overall, N (%)	Adiposity Status		
		NW	OW/OB	SO
N	300	113	87	100
Overall ICH prevalence, N (%)				
Ideal	0 (0)	0 (0)	0 (0)	0 (0)
Intermediate	40 (13)	23 (20)	17 (19)	0 (0)
Poor	260 (87)	90 (80)	70 (81)	100 (100)
ICH components*				
Body mass index percentile, N (%)				
Ideal	113 (38)	113 (100)	0 (0)	0 (0)
Intermediate	20 (7)	0 (0)	20 (23)	0 (0)
Poor	167 (56)	0 (0)	67 (77)	100 (100)
Smoking status, N (%)				
Ideal	298 (99)	112 (99)	87 (100)	99 (99)
Intermediate
Poor	2 (1)	1 (1)	0 (0)	1 (1)
Physical activity, N (%) [†]				
Ideal	57 (19)	28 (25)	17 (19)	12 (12)
Intermediate	222 (74)	84 (74)	66 (76)	72 (72)
Poor	21 (7)	1 (1)	4 (5)	16 (16)
Healthy diet score, N (%)				
Ideal	1 (1)	0 (0)	1 (1)	0 (0)
Intermediate	62 (21)	25 (22)	23 (26)	14 (14)
Poor	237 (79)	88 (78)	63 (72)	86 (86)
Total cholesterol, N (%)				
Ideal	194 (65)	84 (74)	51 (59)	59 (59)
Intermediate	78 (26)	25 (22)	28 (32)	25 (25)
Poor	28 (9)	4 (4)	8 (9)	16 (16)
Blood pressure, N (%)				
Ideal	202 (67)	104 (92)	60 (69)	38 (38)
Intermediate	59 (20)	8 (7)	19 (22)	32 (32)
Poor	39 (13)	1 (1)	8 (9)	30 (30)
Glucose, N (%)				
Ideal	293 (98)	110 (97)	86 (99)	97 (97)
Intermediate	2 (1)	1 (1)	0 (0)	1 (1)
Poor	5 (2)	2 (2)	1 (1)	2 (2)

Percentages may not add up to 100% based on rounded estimates. ICH indicates ideal cardiovascular health; NW, normal weight; OB, obese; OW, overweight; SO, severely obese. *ICH defined by Lloyd-Jones et al as meeting American Heart Association definitions of ideal on 4 health behavior metrics and 3 health factor metrics concurrently. Intermediate cardiovascular health defined as meeting at least 1 intermediate metric and no poor metrics. Poor cardiovascular health defined as having at least 1 poor metric. [†]Moderate and/or vigorous physical activity.

prevalence of overall ICH and subcomponents stratified by adiposity in youth. In addition, we generated a continuous overall ICH sample z-score and ICH subcomponent z-scores

Table 4. Mean z-Score of ICH Components by Adiposity Status (n=300)

	SD*	Adiposity Status		
		NW	OW/OB	SO
N	300	113	87	100
ICH components [†]		ICH z-score (SD)	ICH z-score (SD)	ICH z-score (SD)
Physical activity (SD)	31	0.32 (1.0)	−0.08 (1.0)	−0.32 (0.9)
Healthy diet consumption (SD)				
Fruits/vegetables	1.8	0.04 (0.9)	0.03 (0.9)	−0.07 (1.1)
Fish	0.7	0.03 (0.9)	0.16 (1.1)	−0.23 (0.9)
Whole grains	1.5	0.42 (1.0)	−0.15 (0.9)	−0.29 (0.9)
Sugar-sweetened beverages	54.7	0.07 (1.0)	−0.25 (1.0)	−0.24 (1.0)
Sodium	819	0.13 (0.9)	0.07 (1.1)	−0.25 (1.1)
Overall diet summary score [‡]	...	0.11 (0.9)	0.09 (0.9)	−0.24 (1.1)
Total cholesterol (SD)	29	0.22 (1.0)	−0.16 (0.9)	−0.14 (1.1)
Blood pressure, % (SD)				
SBP percentile	29	0.59 (0.9)	−0.06 (0.9)	−0.61 (0.8)
DBP percentile	22	0.29 (0.9)	−0.01 (1.0)	−0.30 (1.0)
Overall BP percentile summary score [‡]	...	0.51 (0.9)	−0.04 (0.9)	−0.52 (0.9)
Glucose (SD)	9	0.20 (1.0)	−0.16 (1.0)	−0.08 (0.9)
Overall ICH summary score (SD) [‡]	...	0.80 (0.9)	−0.40 (0.7)	−0.58 (0.8)

Interpretation: A z-score ≤ 0 indicates a variable is less than the mean (lower ICH); a z-score ≥ 0 indicates a variable is greater than the mean (higher ICH). BP indicates blood pressure; DBP, diastolic blood pressure; ICH, ideal cardiovascular health; NW, normal weight; OB, obese; OW, overweight; SBP, systolic blood pressure; SO, severely obese.

*Units for SDs: physical activity (min); diet: fruits/vegetables and whole grains (servings/day), fish (servings/wk), sugar-sweetened beverages (oz/wk), sodium (mg/d); total cholesterol and glucose (mg/dL); blood pressure (percentile). SDs for absolute SBP and DBP were 13 and 9 mm Hg, respectively.

[†]Did not include smoking status; only 2 participants were current smokers and dichotomized nature of smoking variable made z-score transformation less straightforward.

[‡]Overall summary z-scores were calculated based on the average of the individual subcomponents: diet (fruits/vegetables, fish, whole grains, sugar-sweetened beverages, and sodium); blood pressure percentile (systolic and diastolic blood pressure percentiles) overall ICH (physical activity, diet, SBP, total cholesterol, and blood glucose). See Methods section for a more detailed description.

across levels of adiposity for an internal comparison. To the best of our knowledge, this is the first study to examine ICH metrics by adiposity status, and to create a continuous ICH z-score that captures the continuous nature of the data. Overall, we found that no participants achieved ICH; 13% and 87% of study participants were in intermediate and poor cardiovascular health, respectively. Importantly, 80% of normal weight, 81% of overweight/obese, and all participants with severe obesity were in poor cardiovascular health. After adjustment for demographics and eligibility for reduced-price or free lunch, participants with overweight/obesity and severe obesity had lower ICH z-scores than normal-weight participants.

Previous studies have found the prevalence of ICH to be low or absent in adolescent,^{22,38,39} young adult,⁴⁰ and adult populations.⁴¹ Our findings are consistent with existing literature, and extend these concerning results to a younger population (mean age: 12.8 years; SD 2.7). Shay and colleagues found a lack of ICH in adolescents aged 12 to 19 years; <50% of adolescents had ≥ 5 ICH components.¹⁵ In the Young Finns study, the largest pediatric cohort study to date, no

participants met the criteria for ICH (mean age: 15.0 years; SD: 0.05).³⁹ Because children are generally considered to be born with ICH,¹ these collective results serve as a considerable reminder that ICH is being lost at younger ages, and that targeted intervention efforts to maintain ICH in early life may be beneficial to prevent the deterioration of ICH in childhood and adolescence. Given that the prevalence of ICH was absent in the current analysis, and that 87% of all participants were in poor cardiovascular health, the functionality of the ICH metric remains uncertain. Furthermore, secular trends for cardiovascular risk factor burden and overweight/obesity have increased or at best plateaued,^{42,43} thus raising concerns that the prevalence of ICH is unlikely to increase in the immediate future. We found that nearly all participants had healthy fasting blood glucose levels and were nonsmokers, even with a large number of participants with severe obesity. Furthermore, only 1 participant met the ideal criteria for the healthy diet score. Previous studies have attempted to address this issue by dichotomizing the number of ICH metrics (≤ 3 or ≥ 4 ICH metrics),³⁹ creating summary scores for total number of ICH metrics present (maximum of 7),^{22,40} or generating a composite

Table 5. Mean (ICH) Diet Subcomponent Consumption and Prevalence of Ideal Consumption by Adiposity Status (n=300)

	Overall	Adiposity Status		
		NW	OW/OB	SO
N	300	113	87	100
Ideal healthy diet subcomponents				
Fruits & vegetables, servings/d (SD)	3.6 (1.8)	3.6 (1.7)	3.6 (1.7)	3.4 (2.2)
Whole grains, servings/d (SD)	2.7 (1.5)	3.3 (1.5)	2.5 (1.4)	2.2 (1.3)
Fish, servings/d (SD)	0.71 (0.70)	0.73 (0.61)	0.82 (0.87)	0.55 (0.53)
SSB, oz/wk (SD)	43 (55)	47 (57)	29 (27)	56 (73)
Sodium, mg/d (SD)	2353 (819)	2466 (698)	2419 (874)	2152 (856)
Ideal healthy diet consumption*				
Fruits & vegetables, N (%)	84 (28)	28 (25)	24 (28)	30 (30)
Whole grains, N (%)	96 (32)	54 (48)	26 (30)	18 (18)
Fish, N (%)	18 (6)	5 (4)	8 (9)	2 (2)
SSB, N (%)	192 (64)	71 (63)	63 (72)	56 (56)
Sodium, N (%)	36 (12)	7 (6)	8 (9)	23 (23)

ICH indicates ideal cardiovascular health; NW, normal weight; OB, obese; OW, overweight; SO, severely obese; SSB, sugar-sweetened beverages.

*Based on American Heart Association guidelines, consistent with Dietary Approaches to Stop Hypertension (DASH) dietary pattern: to consume ≥4.5 cups/d of fruits and vegetables, ≥2 servings/wk of fish, and ≥3 servings/d of whole grains and no more than 36 oz/wk of SSB and 1500 mg/d of sodium.

score (0, 1, or 2 assigned for poor, intermediate, and ideal cardiovascular health, respectively, for each of the 7 factors).¹⁵ Alternatively, it may be beneficial to consider a continuous ICH metric that captures the dynamic physiological state of cardiovascular health.^{24,44,45}

A recent AHA Scientific Statement was published in late 2016, with the intention of being a supplemental document to the “Strategic Impact Goal Through 2020 and Beyond.”³

Steinberger and colleagues specifically discussed challenges and opportunities for cardiovascular health in children and adolescents, and addressed potential modifications that could improve the ICH metric.²³ One of the primary recommendations was that future ICH tools could benefit from prioritizing continuous measures of risk factors. Furthermore, the ICH includes thresholds for behavioral and health factors that are based on percentiles calculated from population estimates.

Table 6. Differences in Overall ICH z-Score by Adiposity Status (n=300)

	Model 1*		Model 2†	
	N=300		N=300	
	ICH z-Score Difference (95% CI)	P Value	ICH z-Score Difference (95% CI)	P Value
Age (per y)	-0.05 (-0.13, 0.03)	0.232	-0.04 (-0.13, 0.02)	0.346
Male (vs female)	0.20 (-0.09, 0.50)	0.181	0.14 (-0.14, 0.34)	0.397
Race: black (vs white)	-0.01 (-0.15, 0.12)	0.849	-0.08 (-0.10, 0.33)	0.761
Tanner stage	0.02 (-0.13, 0.18)	0.786	0.03 (-0.13, 0.15)	0.944
Adiposity status‡				
Normal weight	Referent	...	Referent	...
Overweight/obesity	-1.24 (-1.57, -0.91)	<0.0001	-1.35 (-2.3, -1.1)	<0.0001
Severe obesity	-1.41 (-1.80, -1.01)	<0.0001	-1.45 (-2.9, -0.92)	<0.0001
Free or reduced-price lunch eligibility	-0.10 (-0.92, 0.73)	0.812

All linear regression models examining overall cross-sectional ICH z-score at mean age 12.8±2.7 y. BMI indicates body mass index; CDC, Centers for Disease Control and Prevention; CI, confidence interval; ICH, ideal cardiovascular health.

*Model 1: adjusted for age, sex, race, Tanner stage, and adiposity status.

†Model 2: Model 1+reduced free lunch eligibility.

‡BMI age- and sex-adjusted percentiles based on CDC criteria used to account for pubertal development during adolescence.

The authors argue that thresholds that are relevant to cardiovascular outcomes in adulthood would be more meaningful, but these data are generally nonexistent.²³ It has previously been shown that continuous cluster scores in childhood can be predictive of cardiometabolic dysfunction in adulthood.⁴⁶ In light of these considerations, our results include an evaluation based on comparisons using a continuous z-score in our study sample. After adjustment for demographics and Tanner stage, participants with overweight/obesity and severe obesity had lower overall ICH sample z-scores (-1.35 and -1.45 , respectively) compared with normal-weight participants; results were similar for ICH subcomponents. These results suggest that overweight/obesity and severe obesity are independent predictors of ICH, and the impact of adiposity on ICH may not be fully captured by weighting adiposity and other ICH metrics equally. In addition, prevalence estimates suggest that 80% and 81% of individuals with normal weight and overweight/obesity, respectively, met criteria for poor ICH (Table 3); ICH sample z-scores, however, suggest that individuals with overweight/obesity have a much lower ICH sample z-score (-0.40 ± 0.9) than normal-weight individuals (0.80 ± 0.9) (Table 3). Thus, prevalence estimates alone indicate that individuals with normal weight and overweight/obese have similar ICH, whereas ICH sample z-scores suggest that the overweight/obese group had lower ICH than the normal-weight group. Finally, youth with overweight/obesity and severe obesity are rich targets for primary prevention efforts; additional research is needed on the short-term impacts of lifestyle improvements on ICH metrics in childhood and adolescence.

Examining the prevalence of ICH by adiposity merits independent attention for a variety of reasons. First, the prevalence of overweight and obesity in childhood and adolescence is 33% ($\approx 17\%$ and $\approx 15\%$ are obese and overweight, respectively)⁴²; it is unclear whether these numbers have plateaued or continue to rise.^{42,43} Prevalent severe obesity in children and adolescents, however, has increased from 4% in 1999 to 2004¹⁰ to $>8\%$ in 2013 to 2014.⁷ Second, adiposity in youth is a foundational risk factor for subclinical cardiovascular disease,^{47–50} future obesity,⁵¹ and cardiovascular disease and diabetes mellitus related mortality in adulthood.^{38,52} Mendelian randomization studies support a causal role for obesity in abnormal cardiovascular disease risk factors for the development of adult atherosclerosis.^{19,20} Identifying children based on adiposity who are at risk for clinically evident cardiovascular disease later in life may be an important strategy for cardiovascular disease prevention.^{18,21}

Strengths of this study include the comparison of ICH by adiposity status in a sample encompassing childhood and adolescence, the rare ability to examine this relationship in

youth with severe obesity, comprehensive cardiovascular risk factor assessment, and the generation of continuous ICH sample z-score for use in our study sample (overall and subcomponent z-scores). In the current study, prevalent overweight/obese and severe obesity was higher, by design, than national estimates.^{42,43} Nonetheless, our results are consistent with findings in the Young Finns study, which reported that ICH was rare (1%), ideal fasting glucose and nonsmoking status were most common, and ideal BMI and diet were less common.⁴ Lastly, these results represent the youngest cohort to date where ICH is absent; our results include children who are <12 years of age ($n=117$) and therefore extend beyond the age range specified for ICH in childhood and adolescence (12–19 years). Importantly, higher thresholds for older children and adolescents may incorrectly classify younger children as being in better cardiovascular health, which would likely bias results towards increased ICH.

There are a number of limitations to this study. First, certain variables that impact adiposity, such as genetic predisposition, were not assessed. Study exclusion criteria, however, attempted to identify the most common genetic conditions linked to adiposity or mediation known to impact adiposity status. Second, selection bias remains a possibility; for example, perhaps the participants with severe obesity have a different risk factor profile than the target population of children and adolescents with severe obesity. Nonetheless, the robust sample of youth with severe obesity and concordance of baseline characteristics (Table 1) with known risk factors profiles¹⁴ give confidence to minimal selection bias. Third, it can be challenging to apply criteria from newly developed constructs (ie, ICH) to more commonly used assessment tools for cohort studies or clinical trials. For example, the ICH guidelines consider dietary intake per day or within the previous week, whereas the YAQ food frequency questionnaire asks about dietary patterns in the previous week and month. Strict adherence to AHA ICH criteria in particular was not feasible for all criteria (ie, dietary components or physical activity); reasonable approximations were made. Fourth, the use of z-scores comes with mixed implications.^{53–55} Z-scores afford the use of a continuous scale, standardize the units of the variables of interest, allow comparison across variables, and the ability to evaluate an overall ICH summary z-score as well as compare subcomponent z-scores.^{53,54} Nonetheless, by transforming raw data into z-scores, the original units and clinical meaning are absent,⁵³ and interpretation relies on a 1 SD unit difference, which can have limited clinical meaning, particularly after multiple z-scores are combined. In addition, z-scores are known to perform poorly at extreme values of BMI in youth⁵⁵; we did not calculate a BMI z-score in the current analysis and instead opted to stratify our results by adiposity. Furthermore, z-scores that are calculated using observed means and SDs

from the sample at hand, as was used here for several ICH components, have limited external generalizability because they are generated from a sample and not a target population of interest. Finally, in our primary analysis, we did not include smoking status in our overall z-score because there were very few current ($n=2$) and former ($n=5$) smokers, and smoking status did not have an underlying continuous scale.

This article contributes a number of novel findings to the current literature. First, it is acutely important that children who met the criteria of qualifying for free or reduced-price school lunch programs were among the most significant cohort in poor cardiovascular health. Second, we included a robust sample of individuals with severe obesity, the fastest growing category of obesity in childhood and adolescence. Thus, we were able to differentiate the overall ICH sample z-scores by adiposity status, including severe obesity. Lastly, to the best of our knowledge, this is the first article to present sample z-scores for a continuous ICH metric. If generated using a nationally representative data source, modifying ICH to a continuous metric could further enhance its ability to stratify cardiovascular risk.

Clinical Implications

Pediatricians face numerous challenges when addressing weight management in a clinical setting. One of these hurdles involves addressing behavioral changes for families struggling with weight issues. On the other end of the spectrum, clinicians with expertise in weight management have limited options for clinical management of severe obesity and associated comorbidities. Based on the current findings that ICH status differs across levels of adiposity, this could inform targeted population or clinic-level intervention efforts. Despite the fact that there were no participants in the study with ICH, the prevalence of intermediate ICH was around 20% in both the normal weight and overweight/obese groups. In participants with severe obesity, however, none fell within the definition of intermediate ICH. Thus, clinicians could tailor clinical recommendations for adolescents and children with severe obesity.^{56,57} Because poor ICH was also found in participants with normal weight and overweight/obesity, more intensive and/or different population-level interventions and policy changes could be beneficial. For example, because public school attendance is widely universal, developing school-based policy changes or programs could be considered.^{58,59}

Conclusions

In summary, poor cardiovascular health was highly prevalent in youth, and increased with adiposity status. Overall ICH z-scores were lower across higher levels of adiposity; participants with overweight, obesity, or severe obesity had

lower z-scores than their normal-weight counterparts. Youth remain a rich target for primary prevention efforts targeting behavioral change. Modifying the ICH to a continuous metric could further enhance its ability to stratify cardiovascular risk; data that capture a representative sample in addition to cardiovascular outcomes are critical to assessing the utility of a generalizable continuous metric. Identifying characteristics of children and adolescents who have poor or intermediate ICH based on adiposity status has potential implications for interventions to prevent future cardiovascular disease in youth with obesity. Implementing more aggressive primary prevention intervention efforts in youth with severe obesity should be a priority.

Acknowledgments

The authors thank Annie Mathews, Erin Hurley, and Cameron Naughton for their expert study coordination and management and the participants in this study for donating their time to the project.

Sources of Funding

Funding for this project was provided by the National Heart, Lung, and Blood Institute (R01HL110957, PI: Kelly), the National Center for Advancing Translational Sciences (UL1TR000114, PI: Blazar), and the National Institute of Diabetes and Digestive and Kidney Diseases (P30 DK050456, PI: Levine & Bernlohr). Dr Fyfe-Johnson was supported by National Heart, Lung, and Blood Institute of the National Institutes of Health (T32HL07779, PI: Folsom). The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Disclosures

Dr Kelly serves as a consultant for Novo Nordisk, Orexigen, and Vivus Pharmaceuticals; he does not accept personal or professional income for these activities. Dr Kelly also receives research support from Astra Zeneca Pharmaceuticals in the form of drug/placebo. Dr Fox is a site principal investigator for a pediatric obesity clinical trial sponsored by Novo Nordisk Pharmaceuticals. The remaining authors have no disclosures to report.

References

1. Benjamin EJ, Blaha MJ, Chiuve SE, Cushman M, Das SR, Deo R, de Ferranti SD, Floyd J, Fornage M, Gillespie C, Isasi CR, Jiménez MC, Jordan LC, Judd SE, Lackland D, Lichtman JH, Lisabeth L, Liu S, Longenecker CT, Mackey RH, Matsushita K, Mozaffarian D, Mussolino ME, Nasir K, Neumar RW, Palaniappan L, Pandey DK, Thiagarajan RR, Reeves MJ, Ritchey M, Rodriguez CJ, Roth GA, Rosamond WD, Sasson C, Towfighi A, Tsao CW, Turner MB, Virani SS, Voeks JH, Willey JZ, Wilkins JT, Wu JH, Alger HM, Wong SS, Muntner P; American Heart Association Statistics Committee and Stroke Statistics Subcommittee. Heart disease and stroke statistics—2017 update: a report from the American Heart Association. *Circulation*. 2017;135:e146–e603.

2. Lloyd-Jones DM, Leip EP, Larson MG, D'Agostino RB, Beiser A, Wilson PW, Wolf PA, Levy D. Prediction of lifetime risk for cardiovascular disease by risk factor burden at 50 years of age. *Circulation*. 2006;113:791–798.
3. Lloyd-Jones DM, Hong Y, Labarthe D, Mozaffarian D, Appel LJ, Van Horn L, Greenlund K, Daniels S, Nichol G, Tomaselli GF, Arnett DK, Fonarow GC, Ho PM, Lauer MS, Masoudi FA, Robertson RM, Roger V, Schwamm LH, Sorlie P, Yancy CW, Rosamond WD; 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.
4. Laitinen TT, Pahkala K, Magnussen CG, Viikari JS, Oikonen M, Taittonen L, Mikkilä V, Jokinen E, Hutri-Kähönen N, Laitinen T, Kähönen M, Lehtimäki T, Raitakari OT, Juonala M. Ideal cardiovascular health in childhood and cardiometabolic outcomes in adulthood: the Cardiovascular Risk in Young Finns Study. *Circulation*. 2012;125:1971–1978.
5. Laitinen TT, Pahkala K, Venn A, Woo JG, Oikonen M, Dwyer T, Mikkilä V, Hutri-Kähönen N, Smith KJ, Gall SL, Morrison JA, Viikari JS, Raitakari OT, Magnussen CG, Juonala M. Childhood lifestyle and clinical determinants of adult ideal cardiovascular health: the Cardiovascular Risk in Young Finns Study, the Childhood Determinants of Adult Health Study, the Princeton Follow-Up Study. *Int J Cardiol*. 2013;169:126–132.
6. Laitinen TT, Pahkala K, Magnussen CG, Oikonen M, Viikari JS, Sabin MA, Daniels SR, Heinonen OJ, Taittonen L, Hartiala O, Mikkilä V, Hutri-Kähönen N, Laitinen T, Kähönen M, Raitakari OT, Juonala M. Lifetime measures of ideal cardiovascular health and their association with subclinical atherosclerosis: the Cardiovascular Risk in Young Finns Study. *Int J Cardiol*. 2015;185:186–191.
7. Skinner AC, Perrin EM, Skelton JA. Prevalence of obesity and severe obesity in US children, 1999–2014. *Obesity*. 2016;24:1116–1123.
8. Ryder JR, Kaizer AM, Rudser KD, Daniels SR, Kelly AS. Utility of body mass index in identifying excess adiposity in youth across the obesity spectrum. *J Pediatr*. 2016;177:255–261.e2.
9. Ogden CL, Carroll MD, Lawman HG, Fryar CD, Kruszon-Moran D, Kit BK, Flegal KM. Trends in obesity prevalence among children and adolescents in the United States, 1988–1994 through 2013–2014. *JAMA*. 2016;315:2292.
10. Skelton J, Cook S, Auinger P, Klein J, Barlow S. Prevalence and trends of severe obesity among US children and adolescents. *Acad Pediatr*. 2009;9:322–329.
11. Skinner AC, Perrin EM, Moss LA, Skelton JA. Cardiometabolic risks and severity of obesity in children and young adults. *N Engl J Med*. 2015;373:1307–1317.
12. Kelly AS, Hebbel R, Solovey AN, Schwarzenberg SJ, Metzger AM, Moran A, Sinaiko AR, Jacobs DR Jr, Steinberger J. Circulating activated endothelial cells in pediatric obesity. *J Pediatr*. 2010;157:547–551.
13. Norris AL, Steinberger J, Steffen LM, Metzger AM, Schwarzenberg SJ, Kelly AS. Circulating oxidized LDL and inflammation in extreme pediatric obesity. *Obesity (Silver Spring)*. 2011;19:1415–1419.
14. Kelly AS, Barlow SE, Rao G, Inge TH, Hayman LL, Steinberger J, Urbina EM, Ewing LJ, Daniels SR. Severe obesity in children and adolescents: identification, associated health risks, and treatment approaches: a scientific statement from the American Heart Association. *Circulation*. 2013;128:1689–1712.
15. Shay CM, Ning H, Daniels SR, Rooks CR, Gidding SS, Lloyd-Jones DM. Status of cardiovascular health in US adolescents: prevalence estimates from the National Health and Nutrition Examination Surveys (NHANES) 2005–2010. *Circulation*. 2013;127:1369–1376.
16. Hubert HB, Feinleib M, McNamara PM, Castelli WP. Obesity as an independent risk factor for cardiovascular disease: a 26-year follow-up of participants in the Framingham Heart Study. *Circulation*. 1983;67:968–977.
17. Kannel WB, D'Agostino RB, Cobb JL. Effect of weight on cardiovascular disease. *Am J Clin Nutr*. 1996;63:419S–422S.
18. Juonala M, Magnussen CG, Berenson GS, Venn A, Burns TL, Sabin MA, Srinivasan SR, Daniels SR, Davis PH, Chen W, Sun C, Cheung M, Viikari JS, Dwyer T, Raitakari OT. Childhood adiposity, adult adiposity, and cardiovascular risk factors. *N Engl J Med*. 2011;365:1876–1885.
19. Würtz P, Wang Q, Kangas AJ, Richmond RC, Skarp J, Tiainen M, Tynkynen T, Soinen P, Havulinna AS, Kaakinen M, Viikari JS, Savolainen MJ, Kähönen M, Lehtimäki T, Männistö S, Blankenberg S, Zeller T, Laitinen J, Pouta A, Mäntyselkä P, Vanhala M, Elliott P, Pietiläinen KH, Ripatti S, Salomaa V, Raitakari OT, Järvelin MR, Smith GD, Ala-Korpela M. Metabolic signatures of adiposity in young adults: Mendelian randomization analysis and effects of weight change. *PLoS Med*. 2014;11:e1001765.
20. Kivimäki M, Smith GD, Timpson NJ, Lawlor DA, Batty GD, Kähönen M, Juonala M, Rönnemaa T, Viikari JS, Lehtimäki T, Raitakari OT. Lifetime body mass index and later atherosclerosis risk in young adults: examining causal links using Mendelian randomization in the Cardiovascular Risk in Young Finns study. *Eur Heart J*. 2008;29:2552–2560.
21. Weintraub WS, Daniels SR, Burke LE, Franklin BA, Goff DC Jr, Hayman LL, Lloyd-Jones D, Pandey DK, Sanchez EJ, Schram AP, Whitsel LP; American Heart Association Advocacy Coordinating Committee; Council on Cardiovascular Disease in the Young; Council on the Kidney in Cardiovascular Disease; Council on Epidemiology and Prevention; Council on Cardiovascular Nursing; Council on Arteriosclerosis, Thrombosis and Vascular Biology; Council on Clinical Cardiology, and Stroke Council. Value of primordial and primary prevention for cardiovascular disease: a policy statement from the American Heart Association. *Circulation*. 2011;124:967–990.
22. Oikonen M, Laitinen TT, Magnussen CG, Sinaiko AR, Dwyer T, Venn A, Smith KJ, Hutri-Kähönen N, Pahkala K, Mikkilä V, Prineas R, Viikari JS, Morrison JA, Woo JG, Chen W, Nicklas T, Srinivasan SR, Berenson G, Juonala M, Raitakari OT. Ideal cardiovascular health in young adult populations from the United States, Finland, and Australia and its association with cIMT: the International Childhood Cardiovascular Cohort Consortium. *J Am Heart Assoc*. 2013;2:e000244. DOI: 10.1161/JAHA.113.000244.
23. Steinberger J, Daniels SR, Hagberg N, Isasi CR, Kelly AS, Lloyd-Jones D, Pate RR, Pratt C, Shay CM, Towbin JA, Urbina E, Van Horn LV, Zachariah JP; American Heart Association Atherosclerosis, Hypertension, and Obesity in the Young Committee of the Council on Cardiovascular Disease in the Young; Council on Cardiovascular and Stroke Nursing; Council on Epidemiology and Prevention; Council on Functional Genomics and Translational Biology; and Stroke Council. Cardiovascular health promotion in children: challenges and opportunities for 2020 and beyond: a scientific statement from the American Heart Association. *Circulation*. 2016;134:e236–e255.
24. Bennette C, Vickers A. Against quantiles: categorization of continuous variables in epidemiologic research, and its discontents. *BMC Med Res Methodol*. 2012;12:21.
25. Centers for Disease Control and Prevention. National Center for Health Statistics: clinical growth charts. 2000.
26. Rockett HR, Colditz GA. Assessing diets of children and adolescents. *Am J Clin Nutr*. 1997;65:1116S–1122S.
27. Rockett HR, Breitenbach M, Frazier AL, Witschi J, Wolf AM, Field AE, Colditz GA. Validation of a youth/adolescent food frequency questionnaire. *Prev Med (Baltim)*. 1997;26:808–816.
28. Godin G, Shepard RJ. A simple method to assess exercise behavior in the community. *Can J Appl Sport Sci*. 1985;10:141–146.
29. Godin G, Jobin J, Bouillon H. Assessment of leisure time exercise behavior by self-report: a concurrent validity study. *Can J Public Health*. 1986;77:359–362.
30. Tanner JM, Whitehouse RH. Clinical longitudinal standards for height, weight, height velocity, weight velocity, and stages of puberty. *Arch Dis Child*. 1976;51:170–179.
31. White IR, Royston P, Wood AM. Multiple imputation using chained equations: issues and guidance for practice. *Stat Med*. 2011;30:377–399.
32. Kuczmarski RJ, Ogden CL, Grummer-Strawn LM, Flegal KM, Guo SS, Wei R, Mei Z, Curtin LR, Roche AF, Johnson CL. CDC growth charts: United States. *Adv Data*. 2000;314:1–27.
33. Kuczmarski RJ, Ogden CL, Guo SS, Grummer-Strawn LM, Flegal KM, Mei Z, Wei R, Curtin LR, Roche AF, Johnson CL. 2000 CDC Growth Charts for the United States: methods and development. *Vital Health Stat 11*. 2002;246:1–190.
34. Dibley MJ, Goldsby JB, Staehling NW, Trowbridge FL. Development of normalized curves for the international growth reference: historical and technical considerations. *Am J Clin Nutr*. 1987;46:736–748.
35. Dibley MJ, Staehling N, Nieburg P, Trowbridge FL. Interpretation of Z-score anthropometric indicators derived from the international growth reference. *Am J Clin Nutr*. 1987;46:749–762.
36. Stata Corp. *Stata/SE 14*. College Station, TX: StataCorp; 2015.
37. R Core Team. *R: A Language and Environment for Statistical Computing (Version 3.4.0)*. Vienna: R Found Stat Comput Austria; 2017.
38. Twig G, Yaniv G, Levine H, Leiba A, Goldberger N, Derazne E, Ben-Ami Shor D, Tzur D, Afek A, Shamiss A, Haklai Z, Kark JD. Body-mass index in 2.3 million adolescents and cardiovascular death in adulthood. *N Engl J Med*. 2016;374:2430–2440.
39. Laitinen TT, Ruohonen S, Juonala M, Magnussen CG, Mikkilä V, Mikola H, Hutri-Kähönen N, Laitinen T, Tossavainen P, Jokinen E, Niinikoski H, Jula A, Viikari JS, Rönnemaa T, Raitakari OT, Pahkala K. Ideal cardiovascular health in childhood—longitudinal associations with cardiac structure and function: the Special Turku Coronary Risk Factor Intervention Project (STRIP) and the Cardiovascular Risk in Young Finns Study (YFS). *Int J Cardiol*. 2017;230:304–309.
40. Aatola H, Hutri-Kähönen N, Juonala M, Laitinen TT, Pahkala K, Mikkilä V, Telama R, Koivisto T, Lehtimäki T, Viikari JS, Raitakari OT, Kähönen M. Prospective relationship of change in ideal cardiovascular health status and

- arterial stiffness: the Cardiovascular Risk in Young Finns Study. *J Am Heart Assoc*. 2014;3:e000532. DOI: 10.1161/JAHA.113.000532.
41. Folsom AR, Yatsuya H, Nettleton JA, Lutsey PL, Cushman M, Rosamond WS; ARIC Study Investigators. Community prevalence of ideal cardiovascular health, by the American Heart Association definition, and relationship with cardiovascular disease incidence. *J Am Coll Cardiol*. 2011;57:1690–1696.
 42. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of childhood and adult obesity in the United States, 2011–2012. *JAMA*. 2014;311:806–814.
 43. Skinner AC, Skelton JA. Prevalence and trends in obesity and severe obesity among children in the United States, 1999–2012. *JAMA Pediatr*. 2014;168:561.
 44. Mabikwa OV, Greenwood DC, Baxter PD, Fleming SJ. Assessing the reporting of categorised quantitative variables in observational epidemiological studies. *BMC Health Serv Res*. 2017;17:201.
 45. Collins GS, Ogundimu EO, Cook JA, Le Manach Y, Altman DG. Quantifying the impact of different approaches for handling continuous predictors on the performance of a prognostic model. *Stat Med*. 2016;35:4124–4135.
 46. Kelly AS, Steinberger J, Jacobs DR, Hong C-P, Moran A, Sinaiko AR. Predicting cardiovascular risk in young adulthood from the metabolic syndrome, its component risk factors, and a cluster score in childhood. *Int J Pediatr Obes*. 2011;6:e283–e289.
 47. Hartiala O, Magnussen CG, Kajander S, Knuuti J, Ukkonen H, Saraste A, Rinta-Kiikka I, Kainulainen S, Kähönen M, Hutri-Kähönen N, Laitinen T, Lehtimäki T, Viikari JS, Hartiala J, Juonala M, Raitakari OT. Adolescence risk factors are predictive of coronary artery calcification at middle age: the Cardiovascular Risk in Young Finns Study. *J Am Coll Cardiol*. 2012;60:1364–1370.
 48. Li S, Chen W, Srinivasan SR, Bond MG, Tang R, Urbina EM, Berenson GS. Childhood cardiovascular risk factors and carotid vascular changes in adulthood: the Bogalusa Heart Study. *JAMA*. 2003;290:2271–2276.
 49. Davis PH, Dawson JD, Riley WA, Lauer RM. Carotid intimal-medial thickness is related to cardiovascular risk factors measured from childhood through middle age: the Muscatine Study. *Circulation*. 2001;104:2815–2819.
 50. Raitakari OT, Juonala M, Viikari JSA. Obesity in childhood and vascular changes in adulthood: insights into the Cardiovascular Risk in Young Finns Study. *Int J Obes (Lond)*. 2005;29:S101–S104.
 51. Steinberger J, Moran A, Hong CP, Jacobs DR, Sinaiko AR. Adiposity in childhood predicts obesity and insulin resistance in young adulthood. *J Pediatr*. 2001;138:469–473.
 52. Twig G, Tirosh A, Leiba A, Levine H, Ben-Ami Shor D, Derazne E, Haklai Z, Goldberger N, Kasher-Meron M, Yifrach D, Gerstein HC, Kark JD. Body mass index at age 17 and diabetes mortality in midlife: a nationwide cohort of 2.3 million adolescents. *Diabetes Care*. 2016;39:1996–2003.
 53. Wang Y, Chen H. Chapter 2: Use of Percentile and Z-Scores in Anthropometry. In: Preedy VR, ed. *Handbook of Anthropometry Physical Measures of Human Form in Health and Disease*. Berlin/Heidelberg, Germany: Springer; 2012:29–48.
 54. Sedgwick P. Standardising outcome measures using z scores. *BMJ*. 2014;349:g5878.
 55. Freedman DS, Butte NF, Taveras EM, Lundeen EA, Blanck HM, Goodman AB, Ogden CL. BMI z-Scores are a poor indicator of adiposity among 2- to 19-year-olds with very high BMIs, NHANES 1999–2000 to 2013–2014. *Obesity (Silver Spring)*. 2017;25:739–746.
 56. Expert panel on integrated guidelines for cardiovascular health and risk reduction in children and adolescents: summary report. *Pediatrics*. 2011;128:S213–S256.
 57. Gidding SS, Daniels SR, Kavey RE; Expert Panel on Cardiovascular Health and Risk Reduction in Youth. Developing the 2011 integrated pediatric guidelines for cardiovascular risk reduction. *Pediatrics*. 2012;129:e1311–e1319.
 58. Hayman LL, Williams CL, Daniels SR, Steinberger J, Paridon S, Dennison BA, McCrindle BW. Cardiovascular health promotion in the schools: a statement for health and education professionals and child health advocates from the Committee on Atherosclerosis, Hypertension, and Obesity in Youth (AHOY) of the Council on Cardiovascular Disease in the Young, American Heart Association. *Circulation*. 2004;110:2266–2275.
 59. School health guidelines to promote healthy eating and physical activity. *MMWR Recomm Rep*. 2011;60:1–76.