

Developing global standards for predicting adult overweight and obesity from childhood body mass index – a comparison of estimates obtained from follow up of a pooled international longitudinal cohort to current standards derived from cross-sectional survey data.

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ABSTRACT

Background Historically, cut-points for childhood and adolescent overweight and obesity have been based on population-specific percentiles derived from cross-sectional data. To obtain cut-points that might better predict overweight and obesity in adulthood, we examined the association between childhood body mass index (BMI) and adult BMI status in a longitudinal cohort.

Methods Using the International Childhood Cardiovascular Cohort (i3C) Consortium data from the United States and Finland we determined childhood overweight and obesity cut-points that best predict BMI status at the age of 18 in 3,779 children who were followed up from year 1970 onwards and had at least one childhood BMI measurement between ages 6 and 17 and a BMI measurement specifically at age 18. Logistic regression analysis was used to assess the association between BMI in childhood and adult obesity. Area under the Receiver Operating Characteristic curve (AUROC) was used to assess the ability of fitted models to discriminate different BMI status groups in adulthood. The cut-points were then compared to those defined by the International Obesity Task Force (IOTF) using cross-sectional data, and tested for sensitivity and specificity in a separate, independent longitudinal sample with BMI measurements available from both childhood and adulthood.

Findings The cut-points derived from the longitudinal i3C Consortium data were lower than the IOTF cut-points. Consequently, a larger percentage of the sample was classified as overweight or obese when using the i3C cut-points in the independent sample. Especially for obesity, i3C cut-points was significantly better at discriminating those who would later in life become obese. In the independent sample, the AUROC values for overweight ranged from 0.75 to 0.88 for the i3c cut-points; the corresponding values for the IOTF cut-points ranged from 0.69 to 0.87. For obesity, the AUROC values ranged from 0.84 to 0.90 and 0.57 to 0.76 for the i3c and IOTF cut-points, respectively.

Interpretation The childhood BMI cut-points based on the i3C Consortium longitudinal data provide better predictors of future risk of adult overweight and obesity than estimates based on cross-sectional data. The result is more specific identification of the childhood population at risk of adult overweight or obesity than the currently used IOTF standards.

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INTRODUCTION

The obesity pandemic is currently a major threat to public health.¹ Body mass index (BMI) levels have been shown to track strongly from childhood to adulthood, and childhood BMI levels are important independent predictors of cardiovascular (CV) risk factors and CV morbidity in adulthood.²⁻⁹ For these reasons accuracy in defining levels of BMI in children that predict the risk of obesity in adulthood is important because it defines children that can benefit from direct intervention efforts more efficiently.

The BMI cut points most commonly used for defining childhood overweight and obesity, such as those recommended by the Centers for Disease Control (CDC) and Prevention, and the World Health Organization (WHO), were developed using percentiles for BMI within the chosen child population to define the thresholds for obesity.^{10,11} However, these defined childhood standards have not been examined in relation to adult obesity outcomes, and they may vary depending on which population is selected to define them and on the time period in which that population is measured.

The International Obesity Task Force (IOTF) addressed this challenge by relating the distribution of BMI in children to BMI levels known to be associated with risk of obesity in adults in the same population as the children.¹² The data used to determine the childhood cut-points produced by the IOTF in 2000 were obtained from cross-sectional surveys of 192,727 participants aged 0-25 years between 1963 and 1993 from six populations: Brazil, Great Britain, Hong Kong, the Netherlands, Singapore, and the U.S.A. In the IOTF approach, the proportion of the adult population (defined as 18 year olds) that was overweight or obese was first estimated, using standard adult BMI thresholds of 25 kg/m² and 30 kg/m², respectively. The cut-point for each population was calculated using the LMS method so that each population specific centile curve corresponds to the percentile of adulthood overweight or obesity in that population. To obtain the single cut-points, the population-specific curves

were averaged.¹² A concern about this method of defining childhood BMI risk for adult obesity is whether cross-sectional data provide an accurate estimate. If used in a setting where a secular change in obesity prevalence was occurring in the populations from which the sample participants were chosen, the inferences on cut-points in childhood would not be valid. If the trend in overweight and obesity was upwards the estimates from the cross-sectional approach would underestimate the proportion of children who would become overweight adults. Further, the method use specifies that the same percentage of children will be at risk in all age groups. This is unlikely to be so.

An alternative approach to the cross-sectional comparisons used by the IOTF, WHO, and CDC would be to identify cut-points by examining the association between childhood BMI and adult BMI in the same individuals who had been followed in a cohort as they aged. We aimed to obtain cut-points that might better predict overweight and obesity in adulthood by examining the association between childhood body mass index (BMI) and adult BMI status in a longitudinal cohort, the International Childhood Cardiovascular Cohort (i3C) Consortium that includes seven cohorts from three countries, the U.S.A., Finland, and Australia.

METHODS

The i3C Consortium, has been described previously.¹³ Briefly, the i3C Consortium includes seven large childhood cohorts - five from the United States (Bogalusa Heart Study [BHS, Louisiana]); Minnesota Cohorts [MN, Minnesota]; Muscatine Sftudy [Iowa]; National Growth and Health Study [NGHS, Ohio]; and Princeton Lipid Research Study [PLRS, Ohio]); and one each from Finland ([Cardiovascular Risk in Young Finns Study [YFS]); and Australia (Childhood Determinants of Adult Health Study [CDAH]), which collectively recruited over 40,000 children and adolescents in the 1970s and 1980s for assessment of a

variety of cardiometabolic risk factors. The participants of the study were born between early 1950s and early 1990s, the median birth year being 1970. A subset of each of these cohorts has been re-evaluated at least once in adulthood. For each study, ethical approval was obtained by the appropriate institutional review board. Informed consent was obtained from all parents and adult participants; assent was obtained from participants while they were children/adolescents.

There were 41,086 participants who had BMI measured in childhood (age 3-17). For the main analysis, to allow a direct comparison between i3C and IOTF cut-points, the sample size was restricted to 3,779 participants (9.2% of the original population, Table 1) who had at least one childhood BMI measurement between ages 6 and 17 and a BMI measurement specifically at age 18. Measurements in early childhood (age 3-5) were excluded from the analyses due to insufficient sample size. We conducted parallel analyses using the extended 'young adult' age range of 18-20 (n=5,019, 12.2% of the original population) and 'later young adulthood' age range of 21-29 (n=9,039, 22.0% of the original population). Data from all visits for these individuals were used in the analysis, as described below. The outcome was defined as being overweight ($\text{BMI} \geq 25 \text{ kg/m}^2$) or obese ($\text{BMI} \geq 30 \text{ kg/m}^2$) at the age of 18 in the main analyses and correspondingly being overweight or obese between ages 18-20 and 21-29 in the additional analyses. Because the participants in the CDAH cohort had their youngest adult measurement at age 26 and did not have measurements between ages 18 and 20, they were excluded from the main analysis. However, they were included in the analysis for 'later young adulthood' (ages 21-29 years).

We validated the results in an independent sample for which we used data from the STRIP (Special Turku Coronary Risk Factor Intervention Project) study, which is a longitudinal prospective randomized controlled study to prevent atherosclerosis.¹⁴ The participants were enrolled in the study at their 5-month visit at Turku City well-baby clinics.

At the age of 6 months, 1,062 infants (56.5% of the eligible age cohort) were randomly assigned to an intervention group (n = 540), which was followed biannually, and a control group (n = 522), which was followed biannually up to the age of 7 years and after that on a yearly basis. The intervention, which included dietary counselling as well as information on physical activity and smoking prevention, continued until the study participants were 20 years old.¹⁴ For the analyses in this study, we included individuals based on the same criteria as for the i3C Consortium sample: adult BMI at the age of 18 and at least one BMI measurement in childhood between ages 6 and 17 (n=500). The participants in the STRIP study were 18 years old during the years 2007-09. Despite the intervention setting of the study, BMI was not associated with the intervention status and, therefore, it can be assumed that intervention is not a source of bias in validation.¹⁵ Weight was measured to the nearest 0.1kg with an electronic scale (S10, Soehnle, Murrhardt, Germany) and height to the nearest 0.1cm with a Harpenden stadiometer (Holtain, Crymych, UK). Weight and height were measured with shoes and outer clothes removed. BMI was calculated as weight in kilograms divided by height in meters squared.

In a longitudinal study that continues for as long as the STRIP study, loss to follow-up is inevitable. However, the characteristics of the participants who remained in the study and those who discontinued have been compared on several occasions, with no systematic differences found between the groups.¹⁴⁻¹⁶ Additionally, we compared those who were in the study at the age of 18 years to those who were not and found no differences in sex, BMI, height or weight at baseline (age 0.7 months), 10-year follow-up visit, or parental socioeconomic status (education and occupation) at the age of 13 months. Intervention was, however, modestly associated with loss to follow-up at age 18; as only 44% of those in the sample at age 18 were from the intervention group. Intervention, though was not associated

with BMI and thus the results presented below should not be biased by this difference in proportion of those who remained in the study.

Table 1: Details of the total number of participants who have anthropometric data in between age 6 and 17 and at the age of 18 and age-point specific numbers of observations from i3C Consortium cohorts by sex. The total Ns refer to the number of unique individuals in each cohort. The second row of the table presents the range of birth years for the analysed subsets for each of the cohorts.

	BHS (n=878)		Muscatine (n=536)		NGHS (n=568)	MN (n=769)		PRLS (n=16)		YFS (n=1,012)		Total (N=3,779)	
yob	1958-82		1954-74		1976-78	1966-89		1957-59		1965-74		1954 - 89	
age	M	F	M	F	F*	M	F	M	F	M	F	M	F
6	19	21	40	24		38	37			49	48	146	120
7	60	40	3			172	138					235	178
8	34	33	16	9		328	257					378	299
9	106	107	52	53	322	325	250			85	76	568	808
10	116	82	112	74	543	298	221					526	920
11	66	66	38	33	528	294	223					398	850
12	157	168	166	137	530	386	283			266	306	975	1424
13	156	133	17	14	496	396	306					569	949
14	149	146	178	169	453	391	299	4	4			722	1071
15	216	210	14	28	542	361	272	8	4	458	531	1057	1587
16	139	108	181	171	479	332	245	6	7			658	1010
17	146	162		1	477	291	227	30	20			467	887

*The NGHS cohort includes only females

Abbreviations: yob=year of birth, BHS = Bogalusa Heart Study, NGHS = National Growth and Health Study, MN = Minnesota Cohorts, PRLS = Princeton Lipid Research Study, YFS = Cardiovascular Risk in Young Finns Study, M = Male, F = Female

Statistical methods

Defining the cut-points

All analyses were performed separately by sex and integer age group for ages 6 to 17. The data from different i3C Consortium cohorts were pooled. For those cohort members who had more than one BMI measurement within one age, i.e., who had been measured biannually, we used the first measurement.

We used logistic regression to assess the relation between childhood BMI (explanatory variable) and adult obesity status (response) for each age-sex defined stratum. The linearity in the logit was assessed using fractional polynomials. If a non-linear transformation of BMI was found to best characterize the association between BMI and the logit, the validity of the original logistic regression model was ensured by using suitable transformations of BMI. The calibration of the models was assessed using the Hosmer-Lemeshow goodness-of-fit test.¹⁷ Receiver Operating Characteristic (ROC) curve analysis was used to estimate preliminary childhood cut-points for overweight and obesity. The optimal cut-points were defined from the ROC curve by calculating sensitivity and specificity and deriving Youden's J (*YJ*) index = *sensitivity + specificity - 1*.¹⁸ Sensitivity describes the probability of correctly predicting a participant will be overweight or obese; specificity describes the probability of correctly predicting a participant will be normal weight. *YJ* index summarizes the performance of a predictor in terms of a single statistic. For each analysis, Youden's J index is presented in supplementary table 6.

The cut-point was then calculated based on the equation:

$$\text{Cut - point} = (\text{logit} - \alpha)/\beta$$

Where α and β are the intercept and slope from the logistic regression model, respectively, and logit describes log of the odds in favour of overweight or obesity¹⁹.

The final cut-points at different ages in childhood and adolescence that best predicted being overweight or obese at age 18 for males and females were obtained by fitting a smooth loess curve through the series of preliminary cut-points over age. The smoothing parameter on each loess was obtained by corrected Akaike information criteria (AICc). Using the same methods, we conducted additional analysis by computing cut-points for being overweight or obese in early adulthood during the ages 18-20, and later in adulthood during ages 21-29.

As an additional validation to our cut-points, we investigated how the results would change if we further adjusted the models with ‘region’, these being: Finland (YFS), the US Midwest (MN, NGHS, PRLS, and Muscatine), and BHS. Adjusting for this additional covariate changed the cut-points very little. We also looked into the changes that excluding one of the cohorts would cause by re-analyzing the data excluding one cohort at time. Removing either of the cohorts did not seem to cause major changes to the cut-points.

To determine which of the two estimated sets of age- and sex-specific cut-points in childhood, IOTF or i3C, might more validly estimate risk of adult overweight or obesity, we applied the two sets of cut-points to an independent cohort dataset, the STRIP Study. The children in STRIP study were classified as overweight or obese based on the cut-points at each age point. In order to compare their predictive ability, we determined the area under the ROC curve (AUROC) for both sets of cut-points and computed p-values for comparing the AUROCs. Additionally, we compared i3C cut-points to those defined by the CDC and WHO.

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RESULTS

Table 2 displays the cut-points at different ages in childhood and adolescence that best predict being overweight ($\text{BMI} \geq 25 \text{ kg/m}^2$) or obese ($\text{BMI} \geq 30 \text{ kg/m}^2$) at age 18 in the pooled i3C Consortium data. For the early adulthood responses (age 18-20), the cut-points were similar to those that were derived based on the responses at age 18. For the responses in later adulthood (age 21-29), the cut-points were even lower than when the BMI at age 18 or 18-20 was used. The cut-points from these responses are presented in supplementary Tables 1 and 2 and supplementary Figures 1 and 2.

Table 2 Cut-points for overweight ($\text{BMI} > 25 \text{ kg/m}^2$ at the age of 18) and obesity ($\text{BMI} > 30 \text{ kg/m}^2$ at the age of 18) for males and females.

Age	Age 18 Overweight		Age 18 Obesity	
	Males	Females	Males	Females
6	16.13	15.68	16.81	16.78
7	16.66	16.43	17.55	17.52
8	17.22	17.20	18.29	18.29
9	17.79	18.01	19.03	19.08
10	18.36	18.79	19.78	19.86
11	19.08	19.76	20.58	20.99
12	19.84	20.76	21.38	22.25
13	20.60	21.59	22.28	23.53
14	21.43	22.12	23.48	24.60
15	22.27	22.61	24.73	25.64
16	23.10	23.08	26.00	26.65
17	23.94	23.53	27.31	27.63

Figures 1 and 2 illustrates the cut-points estimated from the i3C data to the IOTF standards.

The i3C estimates are lower than those produced by the IOTF.

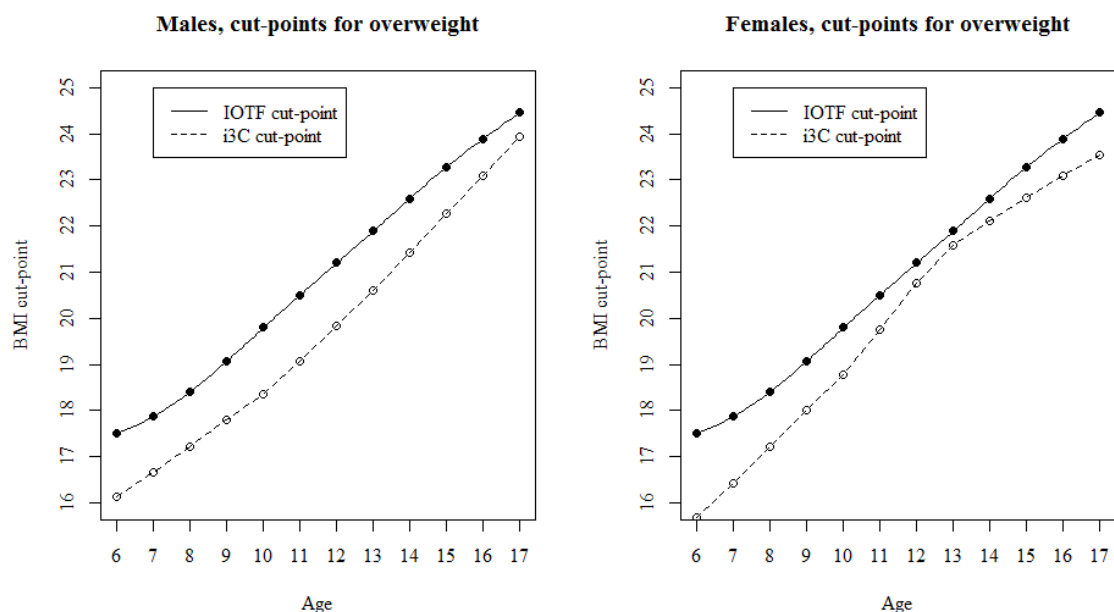


Figure 1 Cut-points for overweight for males and females. The solid line represents the values of International Obesity Task Force (IOTF) cut-points, whereas the dashed line represents cut-points derived from i3C Consortium pooled longitudinal data based on ROC analysis.

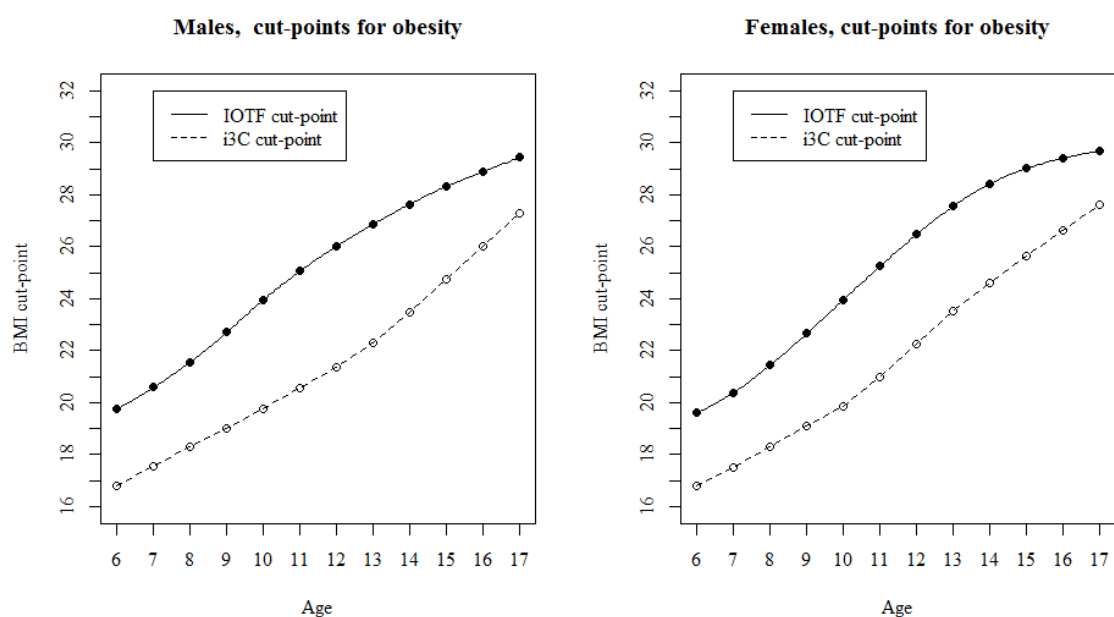


Figure 2 Cut-points for obesity for males and females. The solid line represents the values of IOTF cut-points, whereas the dashed line represents cut-points derived from i3C data using the ROC analysis.

The cut-points were tested by applying them to an independent data set from the STRIP Study. Figure 3 presents the percentages of the STRIP Study participants classified as

overweight or obese based on both sets of cut-points. Since the cut-points derived based on the longitudinal i3C data are lower than the IOTF cut-points, a larger percentage of the participants are classified as overweight or obese based on i3C cut-points.

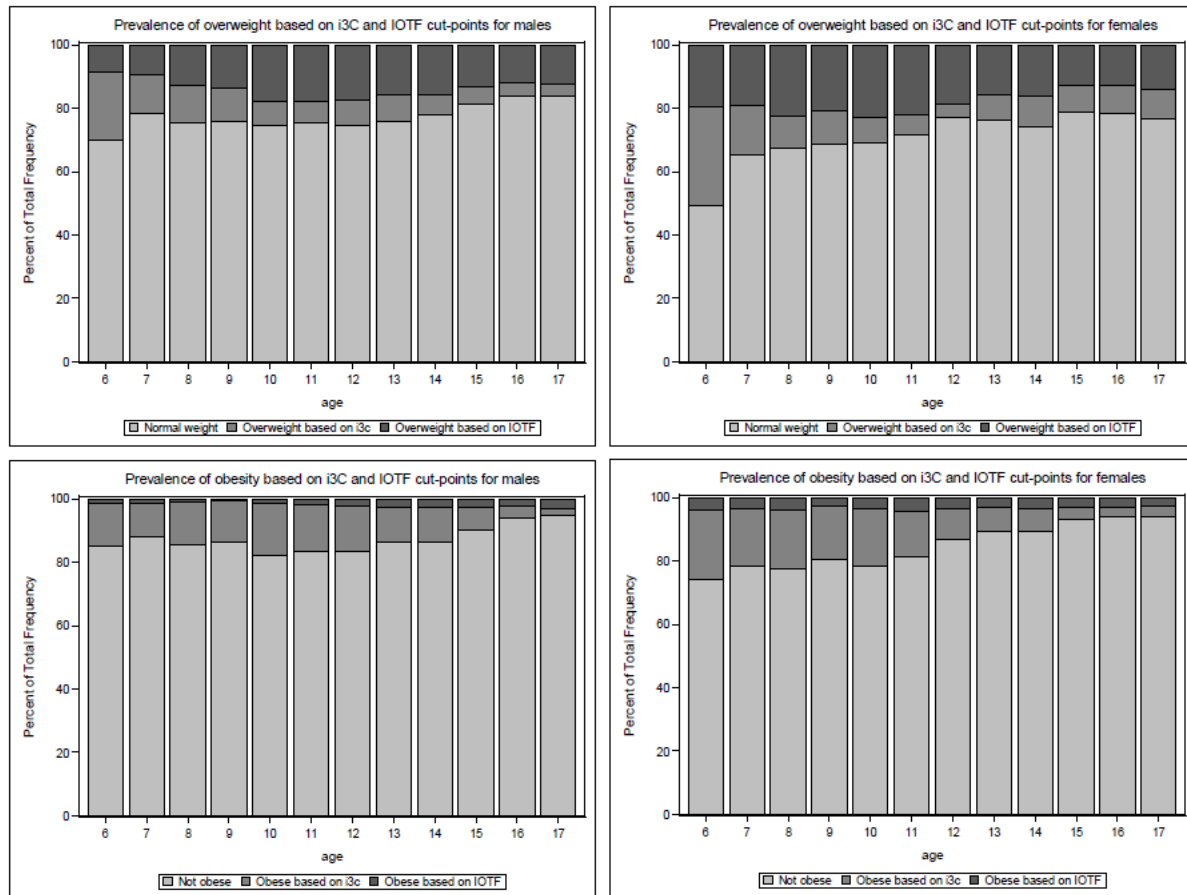


Figure 3 The percentages of STRIP Study population classified as overweight or obese based on i3C and IOTF cut-points

The areas under the ROC curves for both classifiers, i3C and IOTF, and the p-value for their comparison are reported in Tables 3 and 4. Based on the ROC areas and p-values, the lower i3C set of childhood cut-points have better overall ability to discriminate those who will be overweight or obese in adulthood than the IOTF cut-points. For all age points for obesity, and for some age points for overweight, i3C cut-points are statistically significantly superior at predicting the adulthood status than the IOTF cut-points. The i3C cut-points were also lower and had better predictive ability than the CDC cut-points (Supplementary Tables 3, 4 and 5

and Supplementary Figures 3 and 4) and WHO cut-points (Supplementary Tables 5 and 6 and figures 5 and 6). The AUROC for the i3C cut-points ranged from 0.75 to 0.88 for overweight and 0.84 to 0.90 for obesity whereas the corresponding values were 0.69 to 0.83 and 0.66 to 0.88 for the CDC cut-points and 0.72 to 0.88 and 0.67 to 0.88 for the WHO cut-points.

Table 3 The performance of i3C and IOTF BMI cut-points for prediction of overweight in adulthood in the STRIP Study population

Age	AUROC i3C [95% Wald CI]	AUROC IOTF [95% Wald CI]	p
6	0.75 [0.70 ; 0.80]	0.69 [0.62 ; 0.75]	0.05
7	0.73 [0.67 ; 0.79]	0.70 [0.64 ; 0.76]	0.22
8	0.78 [0.72 ; 0.84]	0.73 [0.67 ; 0.79]	0.07
9	0.78 [0.72 ; 0.84]	0.70 [0.64 ; 0.76]	0.01
10	0.79 [0.73 ; 0.84]	0.76 [0.70 ; 0.82]	0.26
11	0.80 [0.75 ; 0.86]	0.76 [0.70 ; 0.82]	0.04
12	0.78 [0.73 ; 0.84]	0.76 [0.70 ; 0.82]	0.24
13	0.81 [0.75 ; 0.86]	0.75 [0.69 ; 0.81]	0.02
14	0.81 [0.75 ; 0.86]	0.79 [0.73 ; 0.85]	0.41
15	0.84 [0.79 ; 0.90]	0.80 [0.74 ; 0.86]	0.05
16	0.87 [0.83 ; 0.92]	0.83 [0.77 ; 0.88]	0.03
17	0.88 [0.84 ; 0.93]	0.87 [0.82 ; 0.92]	0.41

Table 4 The performance of i3C and IOTF BMI cut-points for prediction of obesity in adulthood in the STRIP Study population

Age	AUROC i3C [95% Wald CI]	AUROC IOTF [95% Wald CI]	p
6	0.88 [0.83 ; 0.94]	0.60 [0.51 ; 0.70]	<.001
7	0.87 [0.80 ; 0.95]	0.57 [0.49 ; 0.66]	<.001
8	0.84 [0.75 ; 0.93]	0.57 [0.49 ; 0.66]	<.001
9	0.85 [0.76 ; 0.94]	0.61 [0.51 ; 0.70]	<.001
10	0.86 [0.78 ; 0.93]	0.63 [0.53 ; 0.74]	0.0002
11	0.85 [0.77 ; 0.94]	0.65 [0.55 ; 0.76]	0.001
12	0.86 [0.78 ; 0.95]	0.71 [0.59 ; 0.82]	0.01
13	0.85 [0.76 ; 0.95]	0.71 [0.59 ; 0.82]	0.01
14	0.90 [0.82 ; 0.98]	0.74 [0.63 ; 0.86]	0.01
15	0.89 [0.80 ; 0.98]	0.75 [0.63 ; 0.87]	0.01
16	0.88 [0.79 ; 0.98]	0.76 [0.65 ; 0.88]	0.02
17	0.86 [0.76 ; 0.96]	0.73 [0.62 ; 0.85]	0.02

DISCUSSION

We observed that the overweight/obesity cut-points derived using pooled longitudinal data from the i3C Consortium cohorts are lower than those estimated by the International Obesity Task Force (IOTF) and identify a larger proportion of the childhood population at risk for adult overweight or obesity. Based on the areas under the ROC curve, the set of childhood age- and sex-specific cut-points derived in the present analyses are able to better predict the

risk of adult overweight or obesity than the commonly used IOTF standards. Especially for predicting obesity these lower cut-points seem to be superior.

The reason for the cut-points derived from the i3C Consortium cohort data being lower than those estimated from the cross-sectional survey approach used to derive the IOTF standards is important to consider. Secular change in childhood obesity from the time when the eighteen year old ‘adults’ in the IOTF surveys were themselves children could account for the difference observed. Using the percentage of participants found to be obese at age 18 to define the percentage overweight or obese in concurrent childhood samples gives estimates that are higher than if the data for these 18 year olds as children had been used. This is because the children in the cross-sectional samples have a higher BMI at the same age than their predecessors in the same population when an upward secular trend across the population is occurring. The authors of the IOTF paper have argued that the period in which their survey samples were collected, from 1963 to 1993, was prior to the upward shift in BMI that has occurred in recent decades.¹³ In fact, a modest upturn in prevalence of overweight and obesity in the years during the 1980s and 1990s in the populations from which their samples came was observed.¹⁴ On the other hand, an increase in the prevalence of factors determining development of obesity over the lifespan from childhood to age 18 in the i3C Consortium cohorts would mean that more children of lower BMI would become obese in adulthood than if there had been no secular change. In both scenarios the i3C longitudinal data would generally estimate BMI cut-points in childhood lower than would the IOTF cross-sectional data.

The choice of STRIP study data obtained on participants followed longitudinally from childhood to age 18 in a Finnish sample who were born a decade later than the IOTF or i3C Consortium participants to validate the i3C cut-points, could be criticised. For example, it might be suggested that the greater screening validity observed when i3C Consortium cut-

points were applied to STRIP Study data than when those from IOTF were used was due to the fact STRIP and i3C included participants from Finland. However, this seems unlikely, since the Young Finns contributed only 9 % of the participants in the i3C dataset used for this analysis, with the majority being from the U.SA.

Based on our cut-points the share of obesity-prone children were higher at younger ages. The models used for defining cut-points are more precise and have less uncertainty the closer the response and the explanatory variable are temporally. Thus, the most precise of our cut-points are the ones defined for teenagers in the models with response being overweight or obesity at age 18. The downside of this is that naturally, the analyses where the temporal distance between the response and explanatory variable is bigger exhibit larger uncertainty. In the context of this paper, it appears to lead to lower cut-points and higher prevalence of those who are predicted to be overweight or obese. The phenomena can clearly be seen by looking at the sensitivities, specificities and Youden's J indexes in supplementary tables 6, 7 and 8. Within each table, the Youden's J gets higher with the age of measurement of explanatory variable, i.e., the smaller the temporal distance between the exposure and response. Accordingly, the cut-points defined with age 18 as response appear to have overall higher Youden's J indexes than the cut-points that were defined with age 18-20 or 21-29 as response. It is inarguable that the cut-points for childhood overweight and obesity vary depending on the adult age range chosen. Partly this is explained by the increasing uncertainty, however, the prevalence of overweight and obesity in the chosen age range also affects them. CARDIA data show the prevalence of obesity increases into the 30s and early 40s.²⁰ Which adult age group might be the best for comparison is not an issue we have addressed here as our main focus has been on examining what would be obtained with the cohort approach if it was compared to another major internationally used set of standards which were derived from cross-sectional data. Our choice of age 18 was to ensure we were

able to make comparisons with IOTF. Had we used an older age for our cohort participants for comparison in adulthood we would have most likely found cut-points even lower than we report here. We did repeat our analyses using ages 18-20 or 21-29 for determining which participants developed ‘adult’ overweight and obesity to test this possibility. As shown in those analyses, the estimated cut-points were lower than the cut-points using data from 18-year olds to identify adult obesity.

A major strength of the present study was its ability to utilize longitudinal data on BMI from childhood from different international cohorts. However, as the present analysis was not planned when these cohorts were established, there are some limitations that need to be noted. Most importantly, not all participants in the i3C Consortium cohorts had BMI data available at the age of 18 and this meant we were dealing with a subset of the cohorts. Our additional analysis found that the population that was eligible for the analyses was slightly older and had a higher proportion of females than the original population. However, since the analyses were conducted stratified by sex and age, these differences should not affect the cut-points. In addition, by comparing the participants of each three samples to corresponding non-participants, we noticed that those 3,779 who had BMI measurement at age 18 as well as those 5,019 who had BMI measurement between ages 18-20 had lower age- and sex-adjusted baseline BMI than those who were excluded from these samples. However, the sample of participants who had BMI measured between ages 21-29 did not differ from the non-participants by their age- and sex adjusted baseline BMI.

Of particular importance will be the assessment of whether standards derived from predominantly non-Hispanic Caucasian populations are generalizable to other racial or ethnic groups. Also, when comparing the i3C cut-points to the IOTF cut-points it is important to note that IOTF cut-points were based on populations from countries of different socioeconomic settings and obesity rates (Brazil, Great Britain, Hong Kong, the Netherlands,

Singapore and the U.S.A), whereas the i3C population consists of cohorts only from developed and industrialized countries (U.S.A, Finland and Australia).

The majority of the i3C participants were children in the period, 1970 - 88, and adults approximately twenty years later. IOTF participants were children approximately ten years later on average. Neither have measurements that make the samples 'contemporary'. Even though the i3C estimates are lower than those obtained by IOTF they would still be higher than they should be if adult overweight and obesity has increased since the i3C participants were young adults, which, of course, it has. They will need to be revised with each opportunity that presents as time passes. What we do suggest is that the approach using cohort data has advantages over that using cross-sectional data and that it results in lower estimated cut-points, identifying a higher proportion of the child population as being at risk of future overweight or obesity. As more recent cohorts are able to produce estimates in the same way are developed then these cut-points should be revised, and because of secular trends in adiposity they are likely to be lower than those we have produced. The value of the cut-points derived from the i3C Consortium cohort for use in modern populations globally to screen children for obesity and for public health purposes will only be determined by further testing of the different standards in independent longitudinal samples.

CONCLUSIONS

Our analyses of data from multiple pooled longitudinal cohort studies provides childhood BMI cut-points for adult overweight/obesity prediction. Compared to existing IOTF data, the present cut-points are lower at each childhood age. Using adult data at an older age lowers the childhood cut-points and would appear to improve prediction of subsequent overweight or obesity in adulthood.

AUTHOR CONTRIBUTORSHIP

All author's contribution to this manuscript included interpretation of data for the work and revising it critically for important intellectual content. All authors have given final approval of the version to be published and agree to be accountable for all aspects of the work.

DECLARATION OF INTERESTS

All authors have declared no conflict of interest.

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RESEARCH IN CONTEXT

Evidence before this study

The cut-points for defining childhood overweight and obesity have thus far been based on cross-sectional data in childhood from which population-specific percentiles have been derived for children or, alternatively, on inference from concurrent adult data about the percentage of the population who are overweight and applying this percentile to define the cut-point for children from that population.

Added value of this study

This study provides new cut-points using methodologically preferable longitudinal cohort data. We show that these provide better discrimination of those who will become overweight or obese adults than do those previously derived from cross-sectional data.

Implications of all the available evidence

Using the more precisely defined cut-points from this study will allow intervention efforts to more efficiently identify children and adolescents at risk of becoming overweight or obese in adulthood compared to the estimates obtained by use of current standards.