Downloaded from http://adc.bmj.com/ on August 18, 2015 - Published by group.bmj.com

Prevalence of metabolic syndrome at age 16 using the International Diabetes Federation paediatric definition

J Pirkola,[1] T Tammelin,[2] A Bloigu,[3] A Pouta,[1,3] J Laitinen,[2] A Ruokonen,[4] P Tapanainen,[5] M-R Järvelin,[3,6,7] M Vääräsmäki[1]

[1] Department of Obstetrics and Gynaecology, Oulu University Hospital, Oulu, Finland; [2] Finnish Institute of Occupational Health, Oulu, Finland; [3] Department of Child and Adolescent Health, National Public Health Institute, Oulu, Finland; [4] Department of Clinical Chemistry, Oulu University Hospital, Oulu, Finland; [5] Department of Paediatrics and Adolescence, Oulu University Hospital, Oulu, Finland; [6] Imperial College, London, UK; [7] Institute of Health Sciences, University of Oulu, Finland

Correspondence to: Jatta Pirkola, Department of Obstetrics and Gynecology, Oulu University Hospital, P.O. Box 24, FI-90029 Oulu, Finland; jatta.pirkola@gmail.com

Accepted 20 April 2008
Published Online First 2 May 2008

ABSTRACT

Objective: We estimated the prevalence of metabolic syndrome (MS) in adolescents, using the new International Diabetes Federation (IDF) paediatric definition and compared this with prevalence estimated using the IDF adult definition and five other previously published definitions.

Design: Cross-sectional survey in the prospective general population-based Northern Finland Birth Cohort 1986 (NFBC 1986) at age 16 years.

Setting: Birth cohort in Finland.

Participants: 5665 adolescents (2862 males and 2803 females) clinically examined in 2001–2002.

Main outcome measures: The prevalence of MS using different definitions.

Results: The overall prevalence of MS using the IDF paediatric definition was 2.4% (95% CI 2.0 to 2.8%) at the age of 16 years. Using the IDF adult definition the overall prevalence was lower, 1.7% (CI 1.3 to 2.0%, European cut-offs for waist circumference) and 1.0% (CI 0.7 to 1.3%, North American cut-offs).

Conclusion: In 16-year-old adolescents, the paediatric IDF definition rendered a higher prevalence estimate than the adult definition.

What is already known on this topic

- The prevalence of metabolic syndrome (MS) in children and adolescents depends strongly on the criteria and cut-off points chosen to define the syndrome.
- The International Diabetes Federation (IDF) has recently published its paediatric definition of MS, but no previous data exist on the prevalence of MS in adolescents using the new definition.

What this study adds

- This is the first study to report prevalence of MS using the new IDF paediatric definition and also the first European study on prevalence of MS in adolescents representing the general population.
- In Finnish 16-year-old adolescents the overall prevalence estimate of MS using the new IDF paediatric definition was 2.4%.

Metabolic syndrome (MS) is described as the clustering of obesity, aberrant glucose metabolism, dyslipidaemia and hypertension, and associated with increased risk of later cardiovascular disease (CVD) and diabetes.[1–3] The use of the term "metabolic syndrome" has been debated[4 5] and MS has lacked an internationally accepted, uniform definition until recently. In paediatric studies, different modifications of adult definitions have been used, resulting in inconsistent and non-comparable observations. The International Diabetes Federation (IDF) has recently published its definition of MS for children and adolescents aged 6–16 years.[6] For adolescents over 16 years, the adult definition is recommended.[7]

Obesity contributes strongly to the cluster of MS components in youth.[8] Visceral adiposity in adolescents has been associated with reduced insulin sensitivity.[9] Waist circumference reflects visceral adiposity better than body mass index (BMI), especially in children and adolescents.[10] Therefore, the current paediatric definition of metabolic syndrome is based on increased waist circumference rather than BMI as a measure of obesity. In addition to waist circumference, the waist-to-height ratio has been proposed as a simple means of assessing increased health risk related to increased adiposity on the upper body or even abdominally.[11]

Previous European data on the prevalence of MS in adolescents is based on overweight or obese subpopulations.[12–17] Large-scale general-population-based data on the prevalence of MS in adolescents, is available mainly from North American populations.[18–22] We therefore estimated the prevalence of MS in a large, prospective, population-based birth cohort of European 16-year-old adolescents using the new IDF paediatric definition and compared it to prevalence estimated using the adult definition.[7] To facilitate comparison with North American data, we also estimated the prevalence using the Adult Treatment Panel III (ATP III) definition[23] and its paediatric modification[18] and recent age- and sex-specific-linked IDF and ATP III definitions.[22] In addition, to evaluate the hypertriglycaemic waist phenotype[24] as a definition of MS in adolescents, we estimated the prevalence of the syndrome using that definition.

MATERIALS AND METHODS

Study population

The population-based data derive from the prospectively collected Northern Finland Birth Cohort 1986 (NFBC 1986) described in detail previously.[25]

Downloaded from http://adc.bmj.com/ on August 18, 2015 - Published by group.bmj.com

This longitudinal study covers 99% of all births with an expected delivery date between 1 July 1985 and 30 June 1986 in the two northernmost provinces of Finland (n = 9479). Prospective data have been acquired since the twelfth gestational week. The present analyses included children born only from singleton pregnancies. The latest clinical examination was conducted in 2001–2002, in which 75% of 16-year-old adolescents residing in Finland participated (n = 6798). The anthropometric data (height, weight, waist circumference) were collected, blood pressure measured and fasting blood samples for the analysis of lipids, glucose and insulin drawn. Complete data on all variables used to define MS were available for 83% of those examined (n = 5665).

Anthropometric measures, blood pressure and laboratory analyses

Trained nurses performed the clinical examinations using validated methods with ongoing quality control in place. Height was measured in centimetres and weight in kilograms to one decimal place. Waist circumference was measured at the level midway between the lowest rib margin and the iliac crest. Systolic and diastolic blood pressures were measured in sitting position, after 15 minutes of rest with the cuff on the right upper arm. An oscillometric pressure meter (Omron 705CP) or, if this failed, mercury sphygmomanometer were used. Two readings were taken 2 minutes apart, and the average of the two measurements was used. Blood samples were drawn after fasting overnight. Samples for serum insulin were stored at −20°C and analysed within 7 days. All the other samples were analysed within 24 hours of sampling in the Oulu University Hospital laboratory using ongoing internal/external quality control. Serum insulin was determined by radioimmunoassay (Pharmacia Diagnostics, Uppsala, Sweden). Plasma glucose, serum total cholesterol, high-density lipoprotein (HDL)-cholesterol, low-density lipoprotein (LDL)-cholesterol and triglyceride concentrations were analysed by Cobas Integra 700 automatic analyser (Roche Diagnostics, Basel, Switzerland). The clinical characteristics of the study population are shown in table 1.

Definitions

Metabolic syndrome

MS was defined using the new IDF paediatric definition[6] and, as suggested for adolescents over 16 years, the IDF adult definition.[7] The data were also analysed using the ATP III adult definition[23] and its paediatric modification.[18] A recent Canadian study suggests age- and sex-specific cut-off points linked to IDF and ATP definitions of MS, which were also used in this study.[22] Hypertriglycaemic waist phenotype was evaluated as a definition of MS and defined as fasting serum triglyceride concentration and waist circumference at or above the ninetieth cohort percentile.[24] The definitions, criteria and cut-off points used are summarised in table 2.

Overweight and obesity

Overweight and obesity were defined using the International Obesity Task Force (IOTF) criteria.[29] In addition, abdominal obesity was defined as the ratio of waist circumference to height >0.5.[11]

Insulin resistance

Homeostasis model assessment values for insulin resistance (HOMA-IR) were defined from paired fasting glucose and insulin levels using the validated calculator-programme available at www.dtu.ox.ac.uk.[30]

Statistical analysis

Statistical analysis was performed using SPSS v. 14.0 (SPSS Inc., Chicago, Illinois) and CIA v. 2.1.[31] The distributions of variables for clinical characteristics were skewed and therefore transformed logarithmically to normality. These data are presented as geometric means and 95% CI. The prevalence data are presented in percentage (%) with CI. The differences in components of MS and insulin resistance in five subgroups with the syndrome were assessed using one-way analysis of variance with post hoc Bonferroni correction. A p value <0.05 was considered significant. All analyses were conducted for all adolescents together and by gender.

RESULTS

In this population-based birth cohort the overall prevalence estimate of MS at the mean age of 16.00 (CI 15.99 to 16.00) years using the IDF paediatric definition was 2.4% (n = 134/5665, CI 2.0 to 2.8%, table 3). The IDF adult definition resulted in a lower prevalence estimate of 1.7% (n = 95/5665, CI 1.3 to 2.0%) using European cut-offs for waist circumference

Table 1 Clinical and biochemical characteristics of Northern Finland Birth Cohort 1986 16-year-old adolescents (geometric mean, 95% CI)

Variables	Males (n = 2862) Geometric mean (95% CI)	Females (n = 2803) Geometric mean (95% CI)
Height (cm)	174.8 (174.5 to 175.0)	163.8 (163.6 to 164.1)
Weight (kg)	63.8 (63.4 to 64.2)	56.4 (561 to 56.7)
BMI (kg/m^2)	20.9 (20.8 to 21.0)	21.0 (20.9 to 21.1)
Waist circumference (cm)	75.3 (75.0 to 75.6)	71.5 (71.0 to 71.8)
SBP (mmHg)	121 (120 to 121)	110 (109 to 110)
DBP (mmHg)	68 (68 to 69)	67 (66 to 67)
Glucose (mmol/l)	5.3 (5.3 to 5.3)	5.0 (5.0 to 5.0)
Insulin (pmol/l)	67.1 (65.9 to 68.4)	67.8 (66.8 to 68.8)
Total cholesterol (mmol/l)	4.02 (4.00 to 4.05)	4.36 (4.33 to 4.39)
HDL-cholesterol (mmol/l)	1.29 (1.28 to 1.30)	1.46 (1.45 to 1.47)
LDL-cholesterol (mmol/l)	2.12 (2.10 to 2.14)	2.23 (2.21 to 2.25)
Triglyceride (mmol/l)	0.74 (0.73 to 0.75)	0.77 (0.76 to 0.78)
HOMA-IR	1.26 (1.24 to 1.28)	1.26 (1.24 to 1.28)

All biochemical values are determined from fasting samples.
BMI, body mass index; DBP, diastolic blood pressure; HDL, high-density lipoprotein; HOMA-IR, homeostasis model assessment value for insulin resistance; LDL, low-density lipoprotein; SBP, systolic blood pressure.

Downloaded from http://adc.bmj.com/ on August 18, 2015 - Published by group.bmj.com

Table 2 Summary of different metabolic syndrome definitions

Different definitions of metabolic syndrome	Criteria and cut-off points for components of metabolic syndrome						Diagnostic criteria for metabolic syndrome
	Glucose metabolism	Obesity		Dyslipidaemia		Hypertension	
	Glucose (mmol/l)	BMI (kg/m²)	Waist circumference (cm)	TG (mmol/l)	HDL (mmol/l)	BP (mmHg)	
IDF							
Paediatric definition[4]	≥5.6		M≥87.5, F≥80.0	≥1.7	<1.03	≥130/85	Obesity and ≥2 criteria of 4
			≥P-90 or adult cut-off point if lower				
Age-specific definition[19]	≥5.6		M16y≥91.8	M16y≥1.59	M16y<1.03	M1y6≥128/82	Obesity and ≥2 criteria of 4
			≥P-83*	≥P-89*	<P-26*	≥P-92/P-97*	
			F16y≥77.7	F16y≥1.46	F16<1.27	F16y≥128/84	
			≥P-50*	≥P-89*	<P-43*	≥P-93/P-99*	
Adult definition[5]	≥5.6	≥30	Europe: M≥94, F≥80	≥1.7	<1.03	≥130/85	Obesity (waist circumference or BMI) and ≥2 criteria of 4
			North America: M≥102, F≥88				
ATP III							
Paediatric definition[15]	≥6.1		M16y≥98.1, F16≥92.7	≥1.24	<1.03	≥P-90§	≥3 criteria of 5
			≥P-90†	≥P-90‡	<P-10‡		
Age-specific definition[19]	≥5.6		M16y≥100.6	M16y≥1.59	M16y<1.03	M16y≥128/82	≥3 criteria of 5
			≥P-92*	≥P-89*	<P-26*	≥P-92/P-97*	
			F16y≥85.2	F16y≥1.46	F16y<1.27	F16y≥128/84	
			≥P-72*	≥P-89*	<P-43*	≥P-93/P-99*	
Adult definition[20]	≥5.6		M≥102, F≥88	≥1.7	M<1.03, F<1.30	≥130/85	≥3 criteria of 5
Hypertriglycaemic waist[8]			M≥87.5, F≥82.0	M≥1.30, F≥1.31			2 criteria of 2
			≥P-90¶	≥P-90¶			

Percentiles (P) refer to *NHANES III, NHANES 1999–2000 and 2001 to 2002 data,[22] †NHANES III reference data,[26] ‡Lipid Research Clinics reference data,[27] §NHBPEP reference data[28] and ¶Northern Finland Birth Cohort 1986 data.
ATP III, Adult Treatment Panel III; BMI, body mass index; BP, blood pressure; F, females; HDL, serum high-density lipoprotein concentration; IDF, International Diabetes Federation; M, males; TG, serum triglyceride concentration; y, year.

and an even lower estimate of 1.0% (n = 57/5665, CI 0.7 to 1.3) with North American cut-offs. The prevalence estimate of MS was higher in males than females by all definitions (table 3). The overall prevalence estimate of fulfilling MS criteria by at least one of the seven definitions evaluated (detailed in table 2) was 5.9% (n = 332/5665, CI 5.3 to 6.5%, in males n = 208/2862, 7.3 (CI 6.3 to 8.3%), in females n = 124/2803, 4.4 (CI 3.7 to 5.3%)).

Using the IOTF criteria, the prevalence of overweight was 12.0% (n = 678/5665, CI 11.1 to 12.8%) and the prevalence of obesity was 1.7% (96/5665, CI 1.4 to 2.0, table 4). The prevalence of abdominal obesity defined as waist-to-height ratio >0.5 was 9.8% (n = 556/5665, CI 9.0 to 10.6%). The prevalence of MS rose with increasing BMI. Increased waist-to-height ratio identified 84.2% (n = 85/101, CI 75.6 to 90.7%) of males and 84.8% (n = 28/33, CI 68.1 to 94.9%) of females fulfilling the IDF paediatric criteria for MS.

All biochemical values are determined from fasting samples.

The values for components of MS and HOMA-IR in males and females with MS by different definitions and without MS

Table 3 Prevalence of metabolic syndrome (n, percentage, 95% CI) in the Northern Finland 1986 Birth Cohort

Definition of metabolic syndrome	All (n = 5665) Percentage (95% CI)	Males (n = 2862) Percentage (95% CI)	Females (n = 2803) Percentage (95% CI)
IDF			
Paediatric definition	2.4 (2.0 to 2.8)	3.5 (2.9 to 4.3)	1.2 (0.8 to 1.7)
Age-specific definition	3.2 (2.7 to 3.6)	3.1 (2.5 to 3.9)	3.2 (2.6 to 3.9)
Adult definition			
Europe	1.7 (1.3 to 2.0)	2.2 (1.7 to 2.8)	1.2 (0.8 to 1.7)
North America	1.0 (0.7 to 1.3)	1.4 (1.0 to 1.9)	0.6 (0.4 to 1.0)
ATP III			
Paediatric definition	2.1 (1.7 to 2.5)	3.3 (2.7 to 4.1)	0.8 (0.5 to 1.2)
Age-specific definition	2.8 (2.4 to 3.3)	3.5 (2.8 to 4.2)	2.2 (1.7 to 2.8)
Adult definition	2.3 (1.9 to 2.7)	3.1 (2.5 to 3.8)	1.5 (1.1 to 2.0)
Hypertriglycaemic waist	3.1 (2.7 to 3.6)	3.8 (3.1 to 4.5)	2.5 (2.0 to 3.1)

ATP III, Adult Treatment Panel III; IDF, International Diabetes Federation.

Downloaded from http://adc.bmj.com/ on August 18, 2015 - Published by group.bmj.com

Table 4 Prevalence of metabolic syndrome (percentage, 95% CI) among normal weight, overweight and obese adolescents in the Northern Finland 1986 Birth Cohort

Definition of metabolic syndrome	Normal weight Percentage (95% CI)	Overweight Percentage (95% CI)	Obese Percentage (95% CI)	Waist/height (>0.5) Percentage (95% CI)
Males	n = 2374	n = 368	n = 120	n = 280
IDF				
Paediatric definition	0	13.0 (9.6 to 16.5)	44.2 (35.1 to 53.5)	30.4 (25.0 to 35.7)
Age-specific definition	0	7.8 (5.3 to 10.9)	50.0 (40.7 to 59.3)	30.7 (25.3 to 36.1)
Adult definition				
Europe	0	4.1 (2.3 to 6.6)	39.2 (30.4 to 48.5)	22.1 (17.3 to 27.0)
North America	0	0.5 (0.1 to 2.0)	30.8 (22.7 to 39.9)	13.9 (9.9 to 18.0)
ATP				
Paediatric definition	0.7 (0.4 to 1.1)	8.4 (5.8 to 11.7)	40.0 (31.2 to 49.3)	21.8 (17.0 to 26.6)
Age-specific definition	1.1 (0.8 to 1.7)	7.6 (5.1 to 10.8)	36.7 (28.1 to 45.9)	19.6 (15.0 to 24.3)
Adult definition	0.9 (0.6 to 1.4)	6.3 (4.0 to 9.2)	36.7 (28.1 to 45.9)	18.9 (14.3 to 23.5)
Hypertriglycaemic waist	0.1 (0.03 to 0.4)	13.0 (9.6 to 16.5)	46.7 (37.5 to 56.0)	32.9 (27.4 to 38.4)
Females	n = 2416	n = 310	n = 76	n = 276
IDF				
Paediatric definition	0.2 (0.007 to 0.5)	4.8 (2.7 to 7.9)	17.1 (9.4 to 27.5)	10.1 (6.6 to 13.7)
Age-specific definition	0.8 (0.005 to 1.2)	14.8 (10.9 to 18.8)	32.9 (22.5 to 44.6)	22.8 (17.9 to 27.8)
Adult definition				
Europe	0.2 (0.007 to 0.5)	4.8 (2.7 to 7.9)	17.1 (9.4 to 27.5)	10.1 (6.6 to 13.7)
North America	0	1.6 (0.5 to 3.7)	17.1 (9.4 to 27.5)	6.5 (3.9 to 10.1)
ATP				
Paediatric definition	0	1.9 (0.7 to 4.2)	22.4 (13.6 to 33.4)	8.0 (5.1 to 11.8)
Age-specific definition	0.3 (0.001 to 0.7)	10.0 (6.9 to 13.9)	30.3 (20.2 to 41.9)	18.8 (14.2 to 23.5)
Adult definition	0.2 (0.001 to 0.4)	6.1 (3.7 to 9.4)	25.0 (15.8 to 36.3)	13.4 (9.4 to 17.4)
Hypertriglycaemic waist	0.3 (0.001 to 0.7)	11.6 (8.1 to 15.2)	34.2 (23.7 to 46.0)	21.4 (16.5 to 26.2)

The level of obesity was defined using IOTF criteria.[29]
ATP, Adult Treatment Panel; IDF, International Diabetes Federation; IOTF, International Obesity Task Force.

are shown in table 5. The subjects with the syndrome by at least one definition were taller than those without the syndrome (males 177.5 vs 174.6 cm, $p<0.001$, females 165.6 vs 163.8 cm, $p = 0.001$). Overall, there were no differences in BMI, waist circumference or HOMA-IR between five subgroups defined using: 1. IDF paediatric, 2. IDF age-specific, 3. IDF adult, 4. ATP III paediatric and 5. hypertriglycaemic waist phenotype definitions of MS. The group with hypertriglycaemic waist phenotype had lower fasting serum glucose concentration and systolic blood pressure than groups defined using other definitions of MS.

DISCUSSION

This is the first report on the prevalence of MS in adolescents using the new IDF paediatric definition. This is also the first European general-population-based study on the prevalence of MS in adolescents. The observed overall prevalence estimate of MS using the new IDF paediatric definition was 2.4%. The adult definition, recommended for adolescents over 16 years, yielded a lower prevalence estimate, of 1.7% using European cut-offs for waist circumference and 1.0% using North American cut-offs. According to the paediatric modification of the ATP III definition, the overall prevalence estimate was 2.1%. This is lower than reported in previous population-based studies in North American adolescents aged 12–19 years using the same definition and data from the same time period (6.4%).[20]

Previous large-scale, population-based studies on the prevalence of MS in children and adolescents have been conducted mainly in North America, and previous European paediatric studies have concentrated on overweight or obese subpopulations. In addition to being unselected and general-population based, our study population is ethnically very homogenous, as practically all members are Caucasian. This can be considered an advantage of our study, as well as the high coverage and the detailed data collection. Our study is limited by the fact that the results are based on the clinical examination of the NFBC 1986 at age 16 years and therefore cannot be generalised to younger age groups. However, our results are useful, and very interesting as IDF suggests age 16 as a cut-off point between the paediatric and adult definition. Secular trend suggesting an increase in the prevalence of MS must be taken into account when interpreting the results of this study.[20 32]

A recent Finnish study with data from the year 2001 reports a sixfold increase (4.0% to 25.2%) in the prevalence of MS using the IDF adult definition between males aged 24 and 39 years.[32] As our prevalence estimate in 16-year-old males, using the IDF adult definition, was 2.2%, it seems that the prevalence of MS in males may double between ages 16 and 24 years and increase further thereafter. This can at least partly be explained by the marked increase in prevalence of overweight and obesity from adolescence to adulthood and that weight gain during this period especially accumulates visceral fat.[33 34] The subjects with the syndrome, by at least one of the seven definitions evaluated, were taller than healthy subjects. We do not know whether this is caused by bias (ie, taller subjects have greater waist circumference and are more often diagnosed as having the syndrome) or whether this is caused by "excess fuel" (ie, the subjects with MS have had an excessive supply of nutrients throughout life and therefore are taller).

The IDF defines increased waist circumference in children aged 6–16 years as over the ninetieth percentile or adult cut-off if lower.[6] Waist circumference reference curves are currently available for different populations. In the UK population, in adolescents aged over 16 years, the ninetieth percentile for waist

Downloaded from http://adc.bmj.com/ on August 18, 2015 - Published by group.bmj.com

Table 5 Geometric mean values (95% CIs) for components of the metabolic syndrome (MS) and homeostasis model assessment values for insulin resistance (HOMA-IR) in Northern Finland Birth Cohort (NFBC 1986) subgroups defined using different definitions of MS and without MS

Definition of metabolic syndrome	Glucose (mmol/l)	BMI (kg/m²)	Waist (cm)	TG (mmol/l)	HDL (mmol/l)	SBP (mmHg)	DBP (mmHg)	HOMA-IR
Males								
IDF								
Paediatric definition	5.5 (5.4 to 5.6)	29.1 (28.4 to 29.7)	97.4 (95.9 to 99.0)	1.49 (1.35 to 1.65)	1.03 (0.99 to 1.07)	135 (133 to 138)	76 (74 to 78)	2.46 (2.23 to 2.72)
Age-specific definition	5.4 (5.3 to 5.5)	30.4 (29.6 to 31.1)	100.9 (99.2 to 102.6)	1.45 (1.31 to 1.60)	1.07 (1.03 to 1.11)	136 (133 to 139)	77 (75 to 79)	2.51 (2.26 to 2.78)
Adult definition								
Europe	5.5 (5.4 to 5.6)	30.4 (30.0 to 31.6)	102.0 (100.3 to 103.8)	1.65 (1.46 to 1.87)	1.01 (0.97 to 1.07)	135 (132 to 139)	76 (74 to 78)	2.73 (2.38 to 3.12)
North America	5.5 (5.4 to 5.7)	32.3 (31.4 to 33.3)	105.1 (102.8 to 107.4)	1.72 (1.50 to 1.97)	0.99 (0.93 to 1.06)	136 (131 to 141)	76 (73 to 79)	2.91 (2.46 to 3.45)
ATP								
Pediatric definition	5.5 (5.4 to 5.7)	28.0 (26.9 to 29.0)	93.9 (91.1 to 96.8)	1.71 (1.57 to 1.87)	0.97 (0.93 to 1.01)	138 (136 to 140)	77 (75 to 79)	2.36 (2.11 to 2.65)
Age-specific definition	5.6 (5.5 to 5.7)	27.0 (26.0 to 28.1)	91.5 (88.8 to 94.3)	1.59 (1.43 to 1.78)	0.97 (0.94 to 1.00)	135 (133 to 137)	75 (74 to 77)	2.34 (2.08 to 2.62)
Adult definition	5.7 (5.6 to 5.8)	27.5 (26.4 to 28.7)	92.1 (89.2 to 95.1)	1.70 (1.52 to 1.90)	0.96 (0.93 to 1.00)	135 (132 to 137)	76 (74 to 77)	2.42 (2.15 to 2.73)
Hypertriglycaemic waist	5.3 (5.3 to 5.4)	29.2 (28.5 to 29.9)	97.9 (96.2 to 99.6)	1.82 (1.72 to 1.94)	1.07 (1.03 to 1.11)	130 (128 to 133)	75 (73 to 76)	2.43 (2.26 to 2.61)
Without MS	5.3 (5.3 to 5.3)	20.5 (20.4 to 20.6)	74.1 (73.9 to 74.3)	0.70 (0.69 to 0.71)	1.31 (1.31 to 1.32)	120 (119 to 120)	68 (67 to 68)	1.21 (1.19 to 1.23)
Females								
IDF								
Paediatric definition	5.5 (5.4 to 5.7)	28.1 (26.4 to 29.8)	91.1 (87.4 to 94.9)	1.62 (1.35 to 1.93)	1.12 (1.04 to 1.22)	123 (118 to 129)	77 (73 to 80)	2.60 (2.23 to 3.04)
Age-specific definition	5.3 (5.2 to 5.4)	27.2 (26.5 to 27.9)	88.3 (86.7 to 90.0)	1.37 (1.25 to 1.51)	1.17 (1.12 to 1.21)	121 (118 to 124)	74 (72 to 76)	2.10 (1.90 to 2.32)
Adult definition								
Europe	5.5 (5.4 to 5.7)	28.1 (26.5 to 29.8)	90.7 (87.0 to 94.5)	1.64 (1.38 to 1.95)	1.12 (1.03 to 1.21)	123 (118 to 129)	77 (73 to 80)	2.59 (2.22 to 3.01)
North America	5.5 (5.3 to 5.8)	30.8 (28.7 to 33.1)	97.2 (92.2 to 102.4)	1.82 (1.48 to 2.23)	1.12 (1.00 to 1.25)	126 (120 to 132)	79 (75 to 83)	3.17 (2.60 to 3.86)
ATP								
Paediatric definition	5.4 (5.2 to 5.6)	31.6 (30.0 to 33.4)	97.7 (93.3 to 102.2)	1.73 (1.50 to 2.00)	1.10 (1.01 to 1.20)	126 (122 to 130)	78 (75 to 81)	2.71 (2.30 to 3.21)
Age-specific definition	5.4 (5.2 to 5.6)	28.1 (27.1 to 29.3)	90.6 (88.1 to 93.2)	1.53 (1.39 to 1.70)	1.12 (1.08 to 1.17)	120 (116 to 123)	74 (71 to 76)	2.30 (2.03 to 2.61)
Adult definition	5.4 (5.1 to 5.7)	28.9 (27.6 to 30.2)	92.2 (89.1 to 95.3)	1.51 (1.31 to 1.74)	1.14 (1.08 to 1.20)	124 (120 to 128)	77 (74 to 80)	2.35 (2.01 to 2.75)
Hypertriglycaemic waist	5.1 (5.0 to 5.3)	28.5 (27.6 to 29.4)	92.0 (90.1 to 94.0)	1.73 (1.65 to 1.82)	1.19 (1.14 to 1.25)	117 (114 to 120)	72 (71 to 74)	2.24 (2.00 to 2.50)
Without MS	5.0 (5.0 to 5.0)	20.8 (20.7 to 20.9)	70.8 (70.6 to 71.1)	0.75 (0.74 to 0.76)	1.48 (1.47 to 1.49)	109 (109 to 109)	66 (66 to 66)	1.23 (1.22 to 1.25)

ATP, Adult Treatment Panel; BMI, body mass index; waist, waist circumference; DBP, diastolic blood pressure; HDL, serum high-density lipoprotein concentration; IDF, International Diabetes Federation; SBP, systolic blood pressure; TG, serum triglyceride concentration.

Downloaded from http://adc.bmj.com/ on August 18, 2015 - Published by group.bmj.com

circumference is 81.8 cm in males and 72.6 cm in females.[35] These are substantially lower than the IDF adult cut-offs of 94.0 cm for males and 80.0 cm for females.[7] In our cohort the waist circumference ninetieth percentile in males was 87.5 cm and in females 82.0 cm and thus in the IDF paediatric definition the adult cut-off was used for females. In the IDF adult definition, the waist circumference cut-offs are higher for the North American population (102 cm males, 88 cm females) and in the ATP III-based paediatric definition the ninetieth percentiles for waist circumference are considerably higher (98.1 cm males, 922.7 cm females) than in the UK population or in our cohort. This probably reflects increased abdominal obesity in the North American population compared with our population and may explain the lower prevalence of MS observed in our cohort compared with rates reported from North America.[20]

Obesity is the main component in MS; for example, in the UK population, one-third of obese children and adolescents have MS by modified WHO criteria.[36] This is comparable to our findings. It is noteworthy that in our study the IDF paediatric definition was not fulfilled by any normal-weight male, whereas the prevalence of MS by the same definition was 44.2% in obese males. It has been suggested that the simple message of "keeping your waist circumference to less than half your height" could decrease health risk related to obesity.[11] Our findings support this, as a waist-to-height ratio over 0.5 identified almost 85% of the adolescents with MS defined by the IDF paediatric criteria.

Overall, we did not observe differences in BMI, waist circumference or HOMA-IR between groups identified by different MS definitions. Even though the prevalence estimates using different definitions of MS, varied from 1.0% to 3.1%, it seems that different definitions identify relatively homogenous groups. The hypertriglycaemic waist is the simplest definition of MS and therefore appealing to the clinician. In the present study, the group with hypertriglycaemic waist had lower fasting serum glucose concentration and systolic blood pressure than groups with the syndrome by other definitions. Thus the hypertriglycaemic waist phenotype seems to identify a different group than the other definitions of MS evaluated. Further longitudinal research is necessary to assess the best method for defining MS in adolescents.

In summary we found that the overall prevalence estimate of MS in our study population at age 16 was 2.4% using the new paediatric IDF definition, and 1.7% using the IDF adult definition with European cut-offs for waist circumference. The follow-up of this cohort will provide means to assess the value of different methods of defining MS. Large-scale studies in different populations are necessary to find the best method of identifying adolescents with the syndrome and therefore at risk of later CVD and a target for intervention.

Acknowledgements: The work in this study was conducted with the support of the Academy of Finland, and the European Commission (Framework 5 award QLG1-CT-2000-01643). The authors' work was independent of the funders. We would like to thank Mr Markku Koiranen and Ms Tuula Ylitalo for their support in data delivery and management.

Funding: JP has received funding from the National Graduate School of Clinical Investigation.

Competing interests: None.

Ethics approval: The Ethics Committee of Northern Osthrobothnia Hospital District approved the study.

Patient consent: Adolescents and parents received written and oral information and gave their written informed consent.

REFERENCES

1. **Isomaa B,** Almgren P, Tuomi T, *et al*. Cardiovascular morbidity and mortality associated with the metabolic syndrome. *Diabetes Care* 2001;**24**:683–9.
2. **Eckel RH,** Grundy SM, Zimmet PZ. The metabolic syndrome. *Lancet* 2005;**365**:1415–28.
3. **Litwin M,** Sladowska J, Antoniewicz J, *et al*. Metabolic abnormalities, insulin resistance, and metabolic syndrome in children with primary hypertension. *Am J Hypertens* 2007;**20**:875–82.
4. **Reaven GM.** The metabolic syndrome: requiescat in pace. *Clin Chem* 2005;**51**:931–8.
5. **Gluckman PD.** Evolving a definition of disease. *Arch Dis Child* 2007;**92**:1053–4.
6. **Zimmet P,** Alberti G, Kaufman F, *et al*. The metabolic syndrome in children and adolescents. *Lancet* 2007;**369**:2059–61.
7. **Alberti KG,** Zimmet P, Shaw J, IDF Epidemiology Task Force Consensus Group. The metabolic syndrome--a new worldwide definition. *Lancet* 2005;**366**:1059–62.
8. **Goodman E,** Dolan LM, Morrison JA, *et al*. Factor analysis of clustered cardiovascular risks in adolescence: obesity is the predominant correlate of risk among youth. *Circulation* 2005;**111**:1970–7.
9. **Bacha F,** Saad R, Gungor N, *et al*. Are obesity-related metabolic risk factors modulated by the degree of insulin resistance in adolescents?. *Diabetes Care* 2006;**29**:1599–1604.
10. **Savva SC,** Tornaritis M, Savva ME, *et al*. Waist circumference and waist-to-height ratio are better predictors of cardiovascular disease risk factors in children than body mass index. *Int J Obes Relat Metab Disord* 2000;**24**:1453–8.
11. **McCarthy HD,** Ashwell M. A study of central fatness using waist-to-height ratios in UK children and adolescents over two decades supports the simple message—'keep your waist circumference to less than half your height'. *Int J Obes (Lond)* 2006;**30**:988–92.
12. **Csabi G,** Torok K, Jeges S, *et al*. Presence of metabolic cardiovascular syndrome in obese children. *Eur J Pediatr* 2000;**159**:91–4.
13. **Atabek ME,** Pirgon O, Kurtoglu S. Prevalence of metabolic syndrome in obese Turkish children and adolescents. *Diabetes Res Clin Pract* 2006;**72**:315–21.
14. **Druet C,** Dabbas M, Baltakse V, *et al*. Insulin resistance and the metabolic syndrome in obese French children. *Clin Endocrinol* 2006;**64**:672–8.
15. **Invitti C,** Maffeis C, Gilardini L, *et al*. Metabolic syndrome in obese Caucasian children: prevalence using WHO-derived criteria and association with nontraditional cardiovascular risk factors. *Int J Obes* 2006;**30**:627–33.
16. **Lopez-Capape M,** Alonso M, Colino E, *et al*. Frequency of the metabolic syndrome in obese Spanish pediatric population. *Eur J Endocrinol* 2006;**155**:313–19.
17. **Reinehr T,** de Sousa G, Toschke AM, *et al*. Comparison of metabolic syndrome prevalence using eight different definitions: A critical approach. *Arch Dis Child* 2007 Feb 14 (Epub ahead of print).
18. **Cook S,** Weitzman M, Auinger P, *et al*. Prevalence of a metabolic syndrome phenotype in adolescents: findings from the third National Health and Nutrition Examination Survey, 1988–1994. *Arch Pediatr Adolesc Med* 2003;**157**:821–7.
19. **de Ferranti SD,** Gauvreau K, Ludwig DS, *et al*. Prevalence of the metabolic syndrome in American adolescents: findings from the Third National Health and Nutrition Examination Survey. *Circulation* 2004;**110**:2494–7.
20. **Duncan GE,** Li SM, Zhou XH. Prevalence and trends of a metabolic syndrome phenotype among US adolescents, 1999–2000. *Diabetes Care* 2004;**27**:2438–43.
21. **Lambert M,** Paradis G, O'Loughlin J, *et al*. Insulin resistance syndrome in a representative sample of children and adolescents from Quebec, Canada. *Int J Obes Relat Metab Disor* 2004;**28**:833–41.
22. **Jolliffe CJ,** Janssen I. Development of age-specific adolescent metabolic syndrome criteria that are linked to the Adult Treatment Panel III and International Diabetes Federation criteria. *J Am Coll Cardiol* 2007;**49**:891–8.
23. **Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults**. Executive Summary of The Third Report of The National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, And Treatment of High Blood Cholesterol In Adults (Adult Treatment Panel III). *JAMA* 2001;**285**:2486–97.
24. **Esmaillzadeh A,** Mirmiran P, Azadbakht L, *et al*. Prevalence of the hypertriglyceridemic waist phenotype in Iranian adolescents. *Am J Prev Med* 2006;**30**:52–8.
25. **Jarvelin MR,** Hartikainen-Sorri AL, Rantakallio P. Labour induction policy in hospitals of different levels of specialisation. *Br J Obstet Gynaecol* 1993;**100**:310–15.
26. **Fernandez JR,** Redden DT, Pietrobelli A, *et al*. Waist circumference percentiles in nationally representative samples of African-American, European-American, and Mexican-American children and adolescents. *J Pediatr* 2004;**145**:439–44.
27. **Anon**. Plasma lipid distributions in selected North American populations: The Lipid Research Clinics Program Prevalence Study. The Lipid Research Clinics Program Epidemiology Committee. *Circulation* 1979;**60**:427–39.
28. **Anon**. Update on the 1987 Task Force Report on High Blood Pressure in Children and Adolescents: a working group report from the National High Blood Pressure Education Program. National High Blood Pressure Education Program Working Group on Hypertension Control in Children and Adolescents. *Pediatrics* 1996;**98**:649–58.
29. **Cole TJ,** Bellizzi MJ, Flegal KM, *et al*. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ* 2000;**320**:1240–3.
30. **Wallace TM,** Levy JC, Matthews DR. Use and abuse of HOMA modeling. *Diabetes Care* 2004;**27**:1487–95.

Downloaded from http://adc.bmj.com/ on August 18, 2015 - Published by group.bmj.com

31. **Altman DG,** Machin D, Bruyant TN, *et al*. *Statistics with confidence*. 2nd edn. London: BMJ Books, 2000.
32. **Mattsson N,** Ronnemaa T, Juonala M, *et al*. The prevalence of the metabolic syndrome in young adults. The Cardiovascular Risk in Young Finns Study. *J Intern Med* 2007;**261**:159–69.
33. **Laitinen J,** Pietiläinen K, Wadsworth M, *et al*. Predictors of abdominal obesity among 31-year-old men and women born in Northern Finland in 1966. *Eur J Clin Nutr* 2004:**58**:180–90.
34. **Laitinen J,** Sovio U. Changes in the prevalence of obesity among adolescents – a study of the northern Finland birth cohorts born in1966 and 1986. (Finnish, English abstract). *Suomen Lääkärilehti* 2005:**60**(42):4231–5.
35. **McCarthy HD,** Ellis SM, Cole TJ. Central overweight and obesity in British youth aged 11–16 years: cross sectional surveys of waist circumference. *BMJ* 2003;**326**:624–7.
36. **Viner RM,** Segal TY, Lichtarowicz-Krynska E, *et al*. Prevalence of the insulin resistance syndrome in obesity. *Arch Dis Child* 2005;**90**:10–14.

Archivist

Angiotensin II receptor blockers to slow aortic root dilation in Marfan's syndrome

Marfan's syndrome is an autosomal dominant condition affecting about 1 in 5000 people and is caused by mutations in the gene (*FBN1*) that encodes fibrillin-1. The main cause of premature death in people with Marfan's syndrome is progressive dilation of the aortic root leading to dissection. Current medical treatment is mainly with β blockers. Experiments on genetically engineered mice have shown that one consequence of fibrillin-1 deficiency is excessive signalling by transforming growth factor β (TGF-β). In the mouse model aortic root changes were attenuated or prevented by treatment with either an anti-TGF-β antibody or losartan (an angiotensin II-receptor blocker (ARB) that inhibits TGF-β signalling). Now a retrospective study in Baltimore, USA (Benjamin S Brooke and colleagues. *New England Journal of Medicine* 2008;**358**:2787–95; see also editorial, ibid: 2829–31) has suggested that ARB therapy may slow the rate of aortic dilation in children with Marfan's syndrome.

The study included 18 patients aged between 14 months and 16 years who had been treated with an ARB (losartan in 17 cases, irbesartan in one) for 12–47 months after other treatments had failed to prevent progressive enlargement of the root of the aorta. The mean rate of increase in aortic root diameter decreased significantly from 3.54 mm per year before ARB treatment to 0.46 mm per year during ARB treatment. The rate of aortic root enlargement was reduced during ARB treatment by a mean of 1.47 z scores per year. The rate of dilation of the sinotubular junction was also reduced significantly during ARB treatment.

These findings need to be confirmed by a randomised controlled trial. A national US trial of losartan versus atenolol began in 2007.

Downloaded from http://adc.bmj.com/ on August 18, 2015 - Published by group.bmj.com

Prevalence of metabolic syndrome at age 16 using the International Diabetes Federation paediatric definition

J Pirkola, T Tammelin, A Bloigu, A Pouta, J Laitinen, A Ruokonen, P Tapanainen, M-R Järvelin and M Vääräsmäki

Arch Dis Child 2008 93: 945-951 originally published online May 2, 2008
doi: 10.1136/adc.2007.132951

Updated information and services can be found at:
http://adc.bmj.com/content/93/11/945

These include:

References This article cites 34 articles, 15 of which you can access for free at:
http://adc.bmj.com/content/93/11/945#BIBL

Email alerting service Receive free email alerts when new articles cite this article. Sign up in the box at the top right corner of the online article.

Topic Collections Articles on similar topics can be found in the following collections

Child health (3654)
Adolescent health (302)
Diabetes (324)

Notes

To request permissions go to:
http://group.bmj.com/group/rights-licensing/permissions

To order reprints go to:
http://journals.bmj.com/cgi/reprintform

To subscribe to BMJ go to:
http://group.bmj.com/subscribe/