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# “Leaner and less fit” children have a better cardiometabolic profile than their “heavier and more fit” peers: The Healthy Growth Study

G. Moschonis<sup>a</sup>, V. Mougios<sup>b</sup>, C. Papandreou<sup>a</sup>, C. Lionis<sup>c</sup>,  
G.P. Chrousos<sup>d</sup>, E. Malandraki<sup>a</sup>, Y. Manios<sup>a,\*</sup>

<sup>a</sup> Department of Nutrition and Dietetics, Harokopio University of Athens, 70, El.Venizelou Ave, 17671 Kallithea, Athens, Greece

<sup>b</sup> Department of Physical Education and Sport Science, Aristotle University of Thessaloniki, Thessaloniki, Greece

<sup>c</sup> Clinic of Social and Family Medicine, School of Medicine, Heraklion, University of Crete, Crete, Greece

<sup>d</sup> First Department of Pediatrics, Athens University Medical School, “Aghia Sophia” Children’s Hospital, Athens, Greece

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## KEYWORDS

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**Abstract** *Background and aims:* To examine differences in cardiometabolic risk factors between children of different BMI and fitness levels.

*Methods and results:* From a representative sample of 1222 boys and 1188 girls, aged 9–13 years, anthropometric, body composition, physical activity, cardiorespiratory fitness, biochemical and blood pressure data was collected. The prevalence of overweight and obesity was 29.9% and 11.8% respectively. In both genders, plasma HDL cholesterol concentration was higher in the ‘leaner and less fit’ group (lowest quartile of BMI and lowest quartile of fitness) compared to the ‘heavier and more fit’ (highest quartile of BMI and highest quartile of fitness) and intermediate (all other children) groups ( $p < 0.05$ ). Furthermore, the ‘leaner and less fit’ groups in both genders had lower triacylglycerol concentration, total-to-HDL cholesterol ratio, HOMA-IR, insulin and systolic blood pressure levels compared to the ‘heavier and more fit’ and/or intermediate groups. Similar trends were observed for hypertension in boys and insulin resistance for both genders. Finally, the effect size of being ‘leaner and less fit’ on serum levels of cardiometabolic risk indices was mainly small to medium (i.e. Cohen’s  $d$  0.2–0.5).

\* Corresponding author. Tel.: +30 210 9549156; fax: +30 210 9514759.  
E-mail address: [manios@hua.gr](mailto:manios@hua.gr) (Y. Manios).

**Conclusion:** Leaner and less fit boys and girls had better cardiometabolic risk profiles than their heavier and more fit peers, probably suggesting a higher importance of leanness over fitness in children from a cardiometabolic health benefit perspective.

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## Introduction

The continuous increase in cardiovascular disease (CVD) mortality among adults in Greece and elsewhere is closely associated with risk factors that begin to develop in childhood. The shift from the traditional Mediterranean to a western-type diet, along with the transition from an active to a sedentary lifestyle over the past decades, is of major importance in relation to the occurrence of CVD in Greece [1].

Greece is one of the leading countries in Europe with respect to the prevalence of childhood obesity [2,3]. As adipose tissue accumulates in excessive amounts in the body several metabolic alterations begin to occur [4]. Research has shown that obese children are at higher risk for the development of adverse lipidemic and glycemic profiles compared to lean children [5]. This, is further related to an increase in fatty streaks within the arterial endothelium of children, which may lead to atheromatic plaques in adulthood [6].

While levels of obesity among Greek children are increasing, physical activity and consequently fitness levels are decreasing [7]. There is strong evidence for an inverse association of physical activity and fitness levels with cardiometabolic risk [8]. Several mechanisms have been proposed to mediate the protective effects of physical activity and fitness on cardiometabolic risk including (a) anti-inflammatory action, (b) increased insulin sensitivity, (c) increased non-insulin-dependent glucose uptake, (d) improved lipidemic profile and (e) improved function of hormones and enzymes involved in fat metabolism [9]. In adults, there is strong evidence supporting that low fitness is a stronger risk factor for CVD than obesity [10,11]. However, in children, there are few studies examining the combined effect of different levels of body weight and physical fitness on cardiometabolic risk factors [12]. Such studies are important from a public health perspective, since identification of the interacting or counterbalancing role of different body mass and fitness levels, especially for individuals who fall into the extremes of these health indices, could help public health professionals to develop more effective preventive measures.

Taking the above into consideration, the present study aimed to analyze differences in cardiometabolic risk factors among children after grouping them into quartiles of BMI and fitness levels.

## Methods

### Sampling

The 'Healthy Growth Study' was a cross-sectional epidemiological study initiated in May 2007. Approval to

conduct the study was granted by the Greek Ministry of National Education and the Ethics Committee of Harokopio University of Athens. The study population comprised schoolchildren attending the 5th and 6th grades of primary schools located in municipalities within the wider regions of Attica, Etoloakarnania, Thessaloniki and Iraklio. The sampling procedure is fully described elsewhere [13]. In brief, the sampling of schools was random, multistage and stratified by parental educational level and by the total population of students attending schools within the municipalities.

### Anthropometry and physical examination

Participants were weighed to the nearest 0.1 kg in light clothing and without shoes by using a Seca digital scale (Seca Alpha, Model 770, Hamburg, Germany). Height was measured to the nearest 0.1 cm using a commercial stadiometer (Leicester Height Measure, Invicta Plastics Ltd, Oadby, UK) with the participants barefoot, their shoulders in a relaxed position, their arms hanging freely and their heads in Frankfurt horizontal plane. Two trained members of the research team carried out these measurements.

Body mass index (BMI) was calculated by dividing weight (kg) by height squared ( $m^2$ ). The International Obesity Task Force thresholds were used to categorise children into underweight, normal-weight, overweight and obese [14,15].

Pubertal stage of children was assessed by paediatricians that classified children into five Tanner stages after visual inspection of breast development in girls and genital development in boys [16].

### Body composition

Bioelectrical impedance analysis was used for the assessment of adiposity (Akkern BIA 101; Akkern Srl., Florence, Italy). Participants were instructed to abstain from any solid or liquid food and from any intensive exercise for 4 h prior measurement and not to wear any metal object during measurement. The assessment took place with the pupils lying on a non-conductive surface at neutral temperature. Fat mass, fat-free mass and lean tissue mass were calculated from the resistance and reactance values using valid equations [17].

### Blood pressure

Blood pressure was recorded from the right arm while in a sitting position and after 5 min of rest. A valid automatic Omron M6 Blood Pressure Monitor (Omron Healthcare Europe BV, Hoofddorp, The Netherlands) [18] was used. The measurement was taken twice with a 2-min interval between readings. A third measurement was taken if there was a difference of over 10 mmHg between the previous measurements. The average value of the measurements

was used in analysis. Systolic (SBP) and diastolic blood pressure (DBP) were recorded. Systolic or diastolic hypertension was defined as SBP or DBP above the 95th percentile for gender, age and height [19].

### Biochemical measurements

Early morning blood samples were taken after a 12-hour overnight fast. The parents as well as the children were reminded on the previous day in order to ensure compliance with fasting. Serum triacylglycerols, total cholesterol (TC), high-density lipoprotein cholesterol (HDL) and plasma glucose were measured enzymatically using commercially available kits (Roche Diagnostics, Basel, Switzerland). Low-density lipoprotein cholesterol (LDL) was calculated as:  $LDL = TC - (HDL + triacylglycerols/5)$  [20]. The ratios of TC to HDL and HDL to LDL were also calculated. The National Cholesterol Education Program cut-off points for blood lipids were used to define dyslipidemias [21]. Insulin was measured by a chemiluminescence assay (Kyowa Medex Ltd, Minami-Ishiki, Japan, for Siemens Diagnostics USA). The homeostatic model assessment (HOMA) was used to estimate insulin resistance (IR). The cut-off HOMA value used to define IR was 3.16 [22].

### Physical activity assessment via questionnaire

Physical activity during leisure time was assessed using a standardized questionnaire completed by the children for two consecutive weekdays and one weekend day. Reported activities were assessed as moderate-to-vigorous physical activities (MVPA) provided that they were of intensity higher than 4 metabolic equivalents and included activities such as bicycling, rhythmic-gymnastics, dancing, basketball, soccer, athletics, tennis, swimming, jumping rope and general participation in active outdoor games. Given the age group, MVPA was defined as continuous physical activities causing sweating and heavy breathing for periods longer than 15 min, but with occasional breaks in intensity [23].

### Physical activity assessment via step count

To assess step count as an objective estimate of physical activity, study participants were provided with and instructed to wear a waist-mounted pedometer (Yamax SW-200 Digiwalker, Tokyo, Japan) for one week, i.e. from Monday to Sunday. The pedometer was positioned according to the manufacturer's instructions on the right waistband, vertically aligned with the patella. Children were instructed to wear the pedometer from the time they woke up in the morning until the time they went to bed at night (except when taking a shower, bathing or swimming) and to record their total number of daily steps displayed by the pedometer in diary template before bedtime.

### Cardiorespiratory fitness assessment

Cardiorespiratory fitness was estimated indirectly according to children's performance in the endurance 20-m shuttle run test (ERT). The ERT is a field test included in the European battery of physical fitness tests and

recommended by the Committee of Experts on Sports Research [24]. Based on the test's instructions participants started running at a speed of 8.5 km/h and speed is increased in stages. Participants shuttle between two lines placed 20 m apart, at a pace dictated by a sound signal on an audiotape, which gets progressively faster (by 0.5 km/h every minute). Each stage of the test is made up of several shuttle runs and the score of the participant is the half-stage completed before the child drops out (thus, scores can be 0, 0.5, 1, 1.5, 2 etc). The higher the ERT score, the better the cardiorespiratory fitness. Prior to the test all children received clear and comprehensible instructions on rules and procedures, while during the test they were verbally encouraged by the researchers to succeed their maximal number of laps. The ERT is recommended for large groups of children, since it is reliable, valid, noninvasive, and requires limited facilities [25].

### BMI and fitness categorization

Quartiles of BMI and ERT scores were estimated for boys and girls respectively as indicated in Table 1. Boys and girls in the first quartiles of BMI and ERT were characterized as 'leaner and less fit', while those in the fourth quartiles were characterized as 'heavier and more fit.' All other children were characterized as having intermediate BMI and ERT levels.

### Statistical analysis

Categorical variables were reported as frequencies (%) and continuous variables as means and standard deviations. Student's *t*-test was used to assess differences in continuous variables between boys and girls. Two-sample *z*-test for proportions was used to assess differences in categorical variables between genders, BMI and fitness groups. Multilevel linear and logistic regression analyses were performed for the overall sample, with children nested within classes nested within schools nested within municipalities (four-level random intercept model) using the commands "xtmixed" and "xtmelogit" respectively [26]. In all analyses adjustments were made for children's Tanner stage and mean parental educational level. Finally, effect size was also estimated via the calculation of

**Table 1** Grouping of boys and girls into quartiles on the basis of their BMI and fitness levels.

	Reference values, boys	Reference values, girls
<i>Quartiles BMI range (kg/m<sup>2</sup>)</i>		
1st	13.2–17.4	10.5–17.2
2nd	17.5–19.8	17.3–19.4
3rd	19.9–22.6	19.5–22.2
4th	22.7–43.9	22.3–36.7
<i>Quartiles Fitness range (no of stages at the ERT)</i>		
1st	0–1	0–1
2nd	1.5–2	1.5
3rd	2.5–3.5	2–2.5
4th	4–7	3–7

ERT, endurance run test; BMI, body mass index.

**Table 2** Anthropometric characteristics, fitness and physical activity of the study population.

	Boys (n = 1222)	Girls (n = 1188)	Total (n = 2410)
Weight (kg)	45.6 ± 11.2	45.2 ± 11.0	45.4 ± 11.1
Height (m)	1.48 ± 0.07	1.49 ± 0.08 <sup>a</sup>	1.48 ± 0.08
BMI (kg/m <sup>2</sup> )	20.5 ± 3.7	20.1 ± 3.7 <sup>a</sup>	20.3 ± 3.8
<i>Weight groups</i>			
Underweight (%)	2.6	3.9	3.2
Normal weight (%)	52.7	57.4	55.2
Overweight (%)	30.8	29.0	29.9
Obese (%)	14.0	9.6 <sup>b</sup>	11.8
<i>Fitness levels</i>			
ERT score (no of stages)	2.9 ± 1.7	2.2 ± 1.2 <sup>a</sup>	2.5 ± 1.5
<i>Physical activity level indices</i>			
MVPA (min/d)	79.2 ± 66.2	58.4 ± 58.3	69.0 ± 63.3
Steps/d	14,728 ± 5627	11,790 ± 4298	13,274 ± 5222

Values for continuous variables are expressed as the mean ± SD.

BMI, body mass index; ERT, endurance run test; MVPA, moderate-to-vigorous physical activity.

<sup>a</sup> Significantly different from boys (Student's *t*-test, *P* < 0.001).

<sup>b</sup> Significantly different from boys (two sample *z*-test for proportions, *P* = 0.001).

Cohen's *d*, which shows the magnitude of the difference in cardiometabolic risk indices between 'leaner and less fit' and 'heavier and more fit' groups (i.e. Cohen's *d* value of 0.2, 0.5 and 0.8 indicate small, medium and large effect size respectively) [27]. All reported *P*-values were based on two-sided tests. The level of statistical significance was set at *P* < 0.05. The STATA 11.0 (STATA Corp, College Station, TX, USA) statistical software was used for all statistical analyses.

## Results

Full anthropometric, body composition, physical activity, fitness, biochemical and blood pressure data were collected from 2410 children. Their anthropometric characteristics, fitness scores and physical activity data are presented in Table 2. Overall, the observed prevalence was 3.2% for underweight, 55.2% for normal weight, 29.9% for overweight and 11.8% for obesity. The prevalence of

**Table 3** Body composition and physical activity indices across BMI and fitness groups presented by gender.

	Leaner and less fit	Intermediate groups	Heavier and more fit	<i>P</i> -value <sup>a</sup>	Effect size Cohen's <i>d</i> <sup>d</sup> Leaner and less fit vs. heavier and more fit
<b>Boys</b>					
	(n = 158)	(n = 957)	(n = 107)		
FM (kg)	7.9 ± 2.9 <sup>b</sup>	14.4 ± 7.9	18.4 ± 5.3	<0.001	-2.46
FM (% of body weight)	21.2 ± 5.8	29.3 ± 9.4	34.1 ± 5.8 <sup>c</sup>	<0.001	-2.22
FFM (kg)	28.2 ± 2.9 <sup>b</sup>	31.7 ± 4.2	34.8 ± 4.0 <sup>c</sup>	<0.001	-1.89
LTM (kg)	26.3 ± 2.8 <sup>b</sup>	29.7 ± 4.0	32.5 ± 3.8 <sup>c</sup>	<0.001	-1.86
MVPA (min/day)	60.7 ± 59.8 <sup>b</sup>	80.3 ± 66.4	94.6 ± 69.0 <sup>c</sup>	0.012	-0.52
Step count (no. of steps/day)	14,199 ± 4540	14,741 ± 5772	15,568 ± 5598	0.359	
<b>Girls</b>					
	(n = 231)	(n = 849)	(n = 108)		
FM (kg)	8.3 ± 2.8 <sup>b</sup>	15.0 ± 7.5	19.2 ± 6.0 <sup>c</sup>	<0.001	-2.33
FM (% of body weight)	22.9 ± 6.0 <sup>b</sup>	30.7 ± 79.5	35.2 ± 6.6 <sup>c</sup>	<0.001	-1.95
FFM (kg)	27.5 ± 3.7 <sup>b</sup>	31.4 ± 4.7	34.4 ± 4.7 <sup>c</sup>	<0.001	-1.63
LTM (kg)	26.2 ± 3.5 <sup>b</sup>	29.7 ± 4.4	32.5 ± 4.3 <sup>c</sup>	<0.001	-1.61
MVPA (min/day)	48.7 ± 52.0 <sup>b</sup>	58.8 ± 58.1	74.1 ± 66.8 <sup>c</sup>	0.012	-0.42
Step count (no. of steps/day)	11,756 ± 4137	11,695 ± 4390	12,520 ± 3830	0.781	

BMI, body mass index; FM, fat mass; FFM, fat-free mass; LTM, lean tissue mass; MVPA, moderate to vigorous physical activity.

Leaner and less fit: 1st quartile of BMI and 1st quartile of ERT score; Heavier and more fit: 4th quartile of BMI and 4th quartile of ERT score; Intermediate groups: all other children.

<sup>a</sup> Derived from a four-level random intercept linear regression analysis, after controlling for children's Tanner stage and parental educational level.

<sup>b</sup> *P* < 0.05 "Leaner and less fit" group vs. other two groups.

<sup>c</sup> *P* < 0.05 "Heavier and more fit" group vs. other two groups.

<sup>d</sup> Cohen's *d* indicates the effect size of "leaner and less fit" vs. "heavier and more fit" group.

obesity was higher in boys ( $P = 0.001$ ) and boys had also higher cardiorespiratory fitness levels ( $P < 0.001$ ) compared to girls.

Table 3 displays adiposity and physical activity indices across the BMI and fitness groups by gender. Fat (presented in both kilograms and as percentage of body weight), fat-free and lean tissue mass differed significantly among groups in both boys and girls ( $P < 0.001$ ), being higher in the 'heavier and more fit' group. The same trend was observed for MVPA ( $P = 0.012$ ). Large effect sizes ( $|\text{Cohen's } d| > 1$ ) were observed for fat, fat-free and lean tissue mass indices, whereas small to medium effect sizes were observed for MVPA in girls and boys ( $|\text{Cohen's } d| = 0.42$  and  $0.52$ , respectively).

The mean values of the examined cardiometabolic risk indices across the three groups of BMI and fitness levels are presented by gender in Table 4. In both genders HDLC levels were highest, while TC/HDLC ratio, insulin, HOMA-IR and SBP levels were lowest in the 'leaner and less fit' group ( $P < 0.05$ ). Similarly, DBP levels were found to be lowest in the 'leaner and less fit' group only in boys ( $P < 0.001$ ), while HDLC/LDLC ratio was found to be lowest in the "heavier and more fit" group only in girls ( $P = 0.002$ ).

Effect sizes in boys were small to medium for TC/HDLC ratio, HDLC, DBP, insulin and HOMA-IR levels ( $0.2 > |\text{Cohen's } d| < 0.5$ ) and medium to large for SBP levels ( $|\text{Cohen's } d| = 0.75$ ). In girls, effect sizes were small to medium for HDLC, SBP and triacylglycerols levels as well as for TC/HDLC and HDLC/LDLC ratios ( $0.2 > |\text{Cohen's } d| < 0.5$ ), while large effect sizes were observed for insulin and HOMA-IR levels ( $|\text{Cohen's } d| > 0.8$ ).

Based on the data summarized in Table 5 the percentage of children with IR was found to be lowest in the 'leaner and less fit' groups ( $P < 0.05$ ). Finally, the percentage of boys with systolic hypertension and/or diastolic hypertension was also found to be lowest in the 'leaner and less fit' group ( $P = 0.001$ ).

## Discussion

The present large-scale epidemiological study examined a representative sample of 2410 preadolescents of whom 29.9% were overweight and 11.8% obese. The prevalence of obesity observed in the present study is comparable to that reported by other epidemiological studies in different parts

**Table 4** Cardiometabolic risk profile indices across BMI and fitness groups presented by gender.

	Leaner and less fit	Intermediate groups	Heavier and more fit	<i>P</i> -value <sup>a</sup>	Effect size Cohen's <i>d</i> <sup>d</sup> Leaner and less fit vs. heavier and more fit
<b>Boys</b>					
	( <i>n</i> = 158)	( <i>n</i> = 957)	( <i>n</i> = 107)		
TC (mg/dl)	170.5 ± 30.5	167.3 ± 32.5	168.1 ± 33.4	0.500	
HDLC (mg/dl)	63.3 ± 15.3 <sup>b</sup>	58.6 ± 15.2	57.6 <sup>c</sup> ± 12.3	0.003	0.41
LDLC (mg/dl)	96.5 ± 25.7	96.6 ± 28.1	99.3 ± 30.5	0.196	
Triacylglycerols (mg/dl)	53.6 ± 23.6	60.8 ± 29.6	56.4 ± 24.0	0.049	
TC/HDLC	2.8 ± 0.7 <sup>b</sup>	3.0 ± 0.8	3.02 <sup>c</sup> ± 0.7	0.005	-0.31
HDLC/LDLC	0.7 ± 0.2	0.6 ± 0.3	0.6 ± 0.6	0.846	
Glucose (mg/dl)	92.7 ± 10.1	93.3 ± 10.2	93.8 ± 10.0	0.270	
Insulin (μU/ml)	8.4 ± 4.6 <sup>b</sup>	11.3 ± 9.2	11.1 <sup>c</sup> ± 6.1	0.002	-0.49
HOMA-IR	1.9 ± 1.1 <sup>b</sup>	2.6 ± 2.2	2.5 <sup>c</sup> ± 1.3	0.005	-0.49
SBP (mmHg)	114.2 ± 10.6 <sup>b</sup>	121.3 ± 13.4	123.7 <sup>c</sup> ± 14.4	<0.001	-0.75
DBP (mmHg)	65.8 ± 9.6 <sup>b</sup>	69.3 ± 10.0	70.0 <sup>c</sup> ± 9.3	<0.001	-0.44
<b>Girls</b>					
	( <i>n</i> = 231)	( <i>n</i> = 849)	( <i>n</i> = 108)		
TC (mg/dl)	164.2 ± 32.2	166.0 ± 30.9	162.4 ± 30.6	0.883	
HDLC (mg/dl)	60.5 ± 14.2 <sup>b</sup>	57.3 ± 14.5	56.3 ± 14.0 <sup>c</sup>	0.003	0.29
LDLC (mg/dl)	92.0 ± 25.6	92.7 ± 25.1	94.3 ± 25.6	0.682	
Triacylglycerols (mg/dl)	58.7 ± 18.6 <sup>b</sup>	67.9 ± 29.7	66.7 ± 25.0 <sup>c</sup>	0.001	-0.36
TC/HDLC	2.8 ± 0.5 <sup>b</sup>	3.0 ± 0.8	3.0 ± 0.7 <sup>c</sup>	0.005	-0.33
HDLC/LDLC	0.7 ± 0.2 <sup>b</sup>	0.6 ± 0.3	0.6 ± 0.3 <sup>c</sup>	0.002	0.39
Glucose (mg/dl)	91.1 ± 9.2	91.1 ± 9.3	90.8 ± 8.2	0.525	
Insulin (μU/ml)	9.7 ± 4.9 <sup>b</sup>	14.0 ± 8.2	15.5 ± 7.7 <sup>c</sup>	<0.001	-0.89
HOMA-IR	2.2 ± 1.1 <sup>b</sup>	3.1 ± 1.7	3.4 ± 1.7 <sup>c</sup>	<0.001	-0.84
SBP (mmHg)	117.0 ± 12.3 <sup>b</sup>	121.3 ± 13.5	120.6 ± 13.3 <sup>c</sup>	<0.001	-0.28
DBP (mmHg)	69.3 ± 9.7	71.3 ± 9.7	71.0 ± 9.8	0.214	

TC, Total cholesterol; HDLC, High-density lipoprotein cholesterol; LDLC, Low-density lipoprotein cholesterol; HOMA-IR, Homeostasis Model Assessment of Insulin Resistance.

<sup>a</sup> Leaner and less fit: 1st quartile of BMI and 1st quartile of ERT score; Heavier and more fit: 4th quartile of BMI and 4th quartile of ERT score; Intermediate groups: all other children. Derived from a four-level random intercept linear regression analysis, after controlling for children's Tanner stage and parental educational level.

<sup>b</sup>  $P < 0.05$  "Leaner and less fit" group vs. other two groups.

<sup>c</sup>  $P < 0.05$  "Heavier and more fit" group vs. other two groups.

<sup>d</sup> Cohen's *d* indicates the effect size of "leaner and less fit" vs. "heavier and more fit" group.

**Table 5** Percentages of dyslipidemias, systolic and diastolic hypertension and insulin resistance across BMI and fitness groups presented by gender.

	Boys				Girls			
	Leaner and Less fit (n = 158)	Intermediate groups (n = 957)	Heavier and more fit (n = 107)	P-value <sup>c</sup>	Leaner and Less fit (n = 231)	Intermediate groups (n = 849)	Heavier and more fit (n = 108)	P-value <sup>c</sup>
HDLC < 40 mg/dl	4.4	7.6	4.7	0.959	5.6	10	8.3	0.903
Triacylglycerols >100 mg/dl	3.8	7.9	5.6	0.904	3.0	11.1	12.0	0.506
TC/HDLC > 4.5	1.9	5.7	2.8	0.884	0.9	4.2	2.8	0.849
Systolic hypertension	7.9 <sup>a,b</sup>	24.7 <sup>b</sup>	28.8 <sup>a</sup>	0.001	18.0	25.1	31.0	0.121
Diastolic hypertension	3.9	7.0	3.6	0.936	5.7	8.9	8.0	0.874
Systolic and/or diastolic hypertension	9.9 <sup>a,b</sup>	27.1 <sup>b</sup>	29.7 <sup>a</sup>	0.001	19.7	27.5	33.6	0.085
IR (HOMA-IR<3.16)	3.2 <sup>a,b</sup>	13.9 <sup>b</sup>	13.5 <sup>a</sup>	0.022	6.1 <sup>a,b</sup>	23.6 <sup>b</sup>	31.5 <sup>a</sup>	<0.001

TC: total cholesterol; HDLC: high-density lipoprotein cholesterol; HOMA-IR: homeostasis model assessment–insulin resistance.

Leaner and less fit: 1st quartile of BMI and 1st quartile of ERT score; Heavier and more fit: 4th quartile of BMI and 4th quartile of ERT score; Intermediate groups: all other children.

<sup>a,b</sup> Identical superscript letters denote statistically significant differences ( $P < 0.05$ ) between BMI and ERT groups using the two-sample z-test for proportions.

<sup>c</sup> Derived from multilevel logistic regression analysis, after controlling for children's Tanner stage and mean parental educational level.

of Greece with higher rates in boys than girls. However, when compared to other countries the overall prevalence of childhood obesity in Greece is two- or three-fold higher than the prevalence reported for children in central and northern European countries [2].

Although the existing literature supports a positive association of cardiometabolic risk with BMI [28] and a negative one with fitness levels [17], there are few studies examining the cardiometabolic profile in children, who are at the upper and lower extremes of body mass and fitness levels. A previous study on 375 7–9 year-old children revealed that fitness attenuated the negative effect of BMI on insulin sensitivity, emphasizing the important role of fitness in reducing cardiometabolic risk in overweight and obese children [12]. The biological basis of these observations possibly lies on genetics, adipocytokines and mitochondrial function [29]. Furthermore, a study in adults showed that fit men in the highest quartile of fat mass had a lower risk of CVD mortality than did unfit, lean men [30] concluding that the health benefits of leanness are limited to fit men. Another recent systematic review that compared adults with high BMI and good aerobic fitness to individuals with normal BMI and poor fitness indicated lower cardiovascular mortality in the former group [31].

Contrary to the aforementioned studies, the findings of the present study indicate that the lipidemic and glycemic profiles were better in the 'leaner and less fit' than the 'heavier and more fit' groups in both genders. The interpretation of the diametrically opposed findings reported for children in the current study when compared to adults could have a developmental basis. More specifically, younger people have healthier tissues to begin with and their homeostatic mechanisms work better [32]. A young, lean and unfit person may deal better with the cacostatic load of unfitness than a middle-aged, lean and unfit person.

The opposite may be true for young, fat but fit persons, on whom the cacostatic load of obesity may be higher compared to their middle-aged, fat and fit counterparts.

The present study also showed that the 'leaner and less fit' group exhibited the highest HDLC levels despite the fact that fitness and physical activity are known to be positively related to HDLC levels [33]. However, the effects of exercise training on blood lipid and lipoprotein levels of healthy children and adolescents are equivocal [34], with a meta-analysis reporting no positive effect of aerobic exercise on HDLC levels [35]. Furthermore, the present study reported better triacylglycerol levels, TC/HDLC and LDLC/HDLC ratios in the 'leaner and less fit' category than the 'heavier and more fit' one. Nonetheless, in subsequent analyses, which examined differences in the prevalence of dyslipidemias among the BMI and fitness categories (i.e. % of low HDLC levels, high triacylglycerols levels and TC/HDLC ratio), the statistical significance of these differences did not persist.

Regarding blood pressure, there is evidence for a positive association with BMI [36] and a negative one with physical fitness in children [37]. It is possible that the association between fitness and blood pressure weakens in the presence of increased body fat. Further to unfavorable blood pressure levels increased body fat is also an important risk factor of IR in children [38]. The present study confirmed this by showing higher mean serum HOMA-IR value and prevalence of IR in the 'heavier and more fit' group, thus indicating a more favorable effect of leanness vs. fitness on glycemic control in children.

The current findings should be interpreted on the basis of the study's limitations. The use of BMI to assess weight status is the first limitation, as BMI is not a direct measure of adiposity especially in children [39]. However, the results from the bioelectrical impedance analysis showed that

children in the 'heavier and more fit' group had also the highest fat mass levels. A second limitation is that fitness levels were not assessed with direct measurement of peak oxygen uptake, which is considered the optimal method, but with ERT, which has been reported to introduce error. Nonetheless, in epidemiological studies of large cohorts conducted in community settings (i.e. schools in the present study) it is more practical to use indirect, simple and non-invasive methods to assess indices of health status. A third limitation could be the assessment of children's physical activity levels by a subjective self-report method, (i.e. questionnaire), which is known for its lower accuracy. However the questionnaire used in the present study was previously validated in children [40], while the parallel use of step counters, i.e. an objective method to assess physical activity levels confirmed the findings derived from the questionnaires.

## Conclusions

The present study reported a lower cardiometabolic risk for 'leaner and less fit' children compared to their 'heavier and more fit' peers. These differences suggest that fatness may attenuate the benefits of fitness and physical activity on CVD risk factors in children and that, contrary to the findings in adults, leanness may be more important, from a cardiometabolic health benefit perspective, compared to fitness in children. An intriguing question, then, is at what age the situation is reversed, suggesting the need for future research.

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## Disclosure statement

This manuscript represents an original work, which has not been or is not currently under consideration for publication elsewhere. Before submitting the final version of the manuscript all authors have read and approved it. None of the authors had any potential conflict of interest.

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### Healthy Growth Study Group

1. Harokopio University Research Team/Department of Nutrition and Dietetics: Yannis Manios (Coordinator), George Moschonis (Project manager), Katerina P. Skenderi, Evangelia Grammatikaki, Odysseas Androutsos, Sofia Tanagra, Alexandra Koumpitski, Paraskevi-Eirini Siatitsa,

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3. University of Athens/Medical School: George P. Chrousos, Maria Drakopoulou, Evangelia Charmandari, Panagiota Pervanidou.

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