Original article

# Current data in Greek children indicate decreasing trends of obesity in the transition from childhood to adolescence; results from the National Action for Children's Health (EYZHN) program

K.D. TAMBALIS[1], D.B. PANAGIOTAKOS[1], G. PSARRA[1], L.S. SIDOSSIS[1 2]
[1] Department of Nutrition and Dietetics, Harokopio University, Athens, Greece; [2] Department of Kinesiology and Health, Rutgers University, New Brunswick, USA

Keywords

Obesity • Total • Central • Children • Adolescents

Summary

**Introduction**. *The aim of the study is to present the most recent estimates of obesity (total and central) prevalence in Greek children and associated risk factors.*
**Methods**. *Population data are derived from a yearly, school-based health survey polled in 2015 on 336,014 (51% boys) children aged 4 to 17 years old from almost 40% of all schools of primary and secondary education in Greece. Anthropometric and physical fitness measurements were obtained by trained investigators. Dietary habits, physical activity status, sedentary activities and sleeping hours were assessed through self-completed questionnaires. The gender and age-specific Body Mass Index (BMI) cut-off points were used in order to define BMI groups.*
**Results**. *The prevalence of overweight and obesity in the whole population was 22.2% and 9.0% in boys and 21.6% and 7.5% in girls, respectively. Obesity presented decreasing trends in the transition from childhood to adolescence. Central obesity was diagnosed in 95.3% and 93.5% of the simple obese boys and girls, respectively, in almost two to three of overweight children (68.6% of boys and 64.3% of girls), and in 12% of normal weight children. Age, physical fitness, low adherence to Mediterranean diet, insufficient sleeping hours, inadequate physical activity levels and increased screen time were all associated with higher odds of total and central obesity.*
**Conclusions**. *Serious and urgent actions need to be taken from public health policy makers in order not only to prevent a further increase in obesity rates but, more important, to treat obesity and/or the obesity associated co-morbidities.*

## Introduction

In today's society the prevalence of obesity in children and adolescents has been recognized as a global epidemic [1]. In the European Union the number of overweight children is expected to rise by 1.3 million per year, with more than 300.000 of them becoming obese each year [2]. Greece is among the European countries with the highest levels of childhood obesity [3]. It is estimated that the prevalence of overweight and obesity is markedly different among children and adolescents in Greece and elsewhere [4, 5]. Childhood obesity has been associated with the development of cardiovascular diseases, diabetes, metabolic syndrome, and excess weight status in adult life [6], and moreover, it influences social and psychological functioning of children [7]. Central obesity (i.e., abdominal subcutaneous and visceral adiposity) is an important risk factor for insulin resistance and an identifier of cardio-metabolic disorders and cardiovascular disease in later life [8]. Waist Circumference (WC) and Waist-to-Height Ratio (WtHR) are measurement methods for evaluation of central obesity. It is estimated that they predict better than Body Mass Index (BMI) cardio-metabolic risks [9]. The causes of childhood obesity are multi-factorial, including genetic predisposition, perinatal factors, and lifestyle, environmental and socioeconomic variables [6]. In the last decade, the Greek government in collaboration with several independent authorities has significantly forced public health efforts aiming to reduce childhood obesity. EYZHN (National Action for Children's Health) is an intertemporal program aiming to record health- and lifestyle-related parameters of the total student population of Greece.
To our knowledge, only a few studies [4, 10-12] have currently estimated the prevalence of total or abdominal obesity in Greek children and adolescents based on a national representative sample; most of them have drawn conclusions from selected geographic areas or from a deteriorated age range [10-12]. Accordingly, the aim of the present study is: (a) to examine the prevalence of total and central obesity groups among 4- to 17-y-old children and adolescents as a basis for effective prevention strategies and (b) to investigate whether there is an association between several anthropometric and lifestyle factors and total/central obesity.

## Methods

### Participants

Population-based, representative data were derived from a nation-wide, school-based survey under the auspices of the Ministry of Education. Specifically, anthropometric, physical activity, sedentary habits, nutrition, and physical fitness data along with information on age and sex were collected from March 2015 to May 2015. In total, 336,014 (51% boys and 49% girls) children aged 4 to 17 years old from pre-elementary (4- to 5-y-old), elementary (6- to 11-y-old) and middle (12- to 17-y-old) public and private schools agreed to participate in the study (participation rate was almost 40% of the total population). The working sample was representative of the entire Greek population (chi-square p-value as compared to the current sample with the age-sex distribution of all Greek areas = 0.93). The participation rates assured the proportional enrollment of children based on the urban/rural areas student population distribution.

### Assessment of demographic and anthropometric measurements

Demographic information of students (e.g., school, class, gender and date of birth) was obtained from each school headmaster. Children's height, weight and waist circumference were measured in the morning, using a standardized procedure. Data collection activity in each school was completed in one working day. Children wear little clothing and stand with feet close together, arms at the side and body weight evenly distributed. The exact ages of the participants were calculated from birth and examination dates. Weight was measured in the standing upright position with electronic scales with a precision of 100 g. Standing height was determined to the nearest 0.5 cm with the child's weight being equally distributed on the two feet, head back and buttocks on the vertical land of the height gauge. BMI was calculated as the ratio of body weight to the square of height ($kg/m^2$). Waist circumference was measured at the midpoint between the lower margin of the least palpable rib and the top of the iliac crest, using a flexible measure to the nearest 0.1 cm. Underweight (3 grades), normal weight, overweight and obese children were classified using the International Obesity Taskforce age- and gender-specific BMI cut-off criteria [13, 14], as the most proper for epidemiologic studies [15]. Central obesity was defined as waist circumference (cm) to height (cm) ratio (WtHR) $\geq 0.5$, given that this specific cut-off point has been established suitable for the prediction of obesity-related cardiometabolic abnormalities in children and adolescents [16].

All measurements were repeated; if the measurements were within 1 cm of one another, the average was calculated. All anthropometric measurements were performed by trained professionals (teachers of physical education). Specifically, measurements were performed by one teacher of physical education in each class. All physical education professionals were instructed through a detailed and extended manual of operations and followed a standardized procedure of measurements in order to minimize the potential inter-rate variability among schools. The physical education teachers were first trained by school advisor of physical education for accurate anatomical landmarks, subject positioning and measurement techniques. Verbal informed consent for the child to participate in the measurements was taken from physical education teachers. As the measurements were included in an obligatory school program, verbal informed consent was considered sufficient.

### Assessment of physical fitness levels

The Euro-fit PF test battery was used to evaluate children's PF levels [17], initially proposed by the Council of Europe and used systematically from many European countries during the last decades. The battery consists of five tests: (a) a multi-stage 20 m shuttle run test (20 m SRT), to estimate aerobic performance; (b) a maximum 10 × 5 m shuttle run test (10 × 5 m SRT) from a standing start to evaluate speed and agility; (c) a sit-ups test in 30 seconds (SUs), in which the student lies on the mat with the knees bent at right angles, feet flat on the floor and held down by a partner, to measure the endurance of the abdominal and hip-flexor muscles; (d) a standing long jump (SLJ), where the children are asked to bend their knees with their arms in front of them, parallel to the ground, then swing both arms and push off vigorously and jump as far as possible, trying to land with their feet together and stay upright, to evaluate lower body explosive power; and (e) a sit and reach (SR) test that involves sitting on the floor with legs stretched out straight ahead without shoes to measure flexibility. Two trials were allowed for the SLJ, SR, SUs, and 10 × 5 m SRT, with the best performance of each recorded. All five fitness tests were administered during the physical education class by physical education professionals, who were instructed through a detailed manual of operations and followed a standardized procedure of measurements in order to minimize the inter-rate variability among schools.

### Assessment of dietary habits

Participating children's dietary, physical activity and sedentary habits were recorded via the use of an electronic questionnaire. It was completed at school with the presence and assistance of their teachers and/or information technology professors, all previously provided with specific written guidelines for its proper completion. This was done in order to provide an accurate reflection of their habits and for a standardized evaluation protocol to be implemented among all participating schools. Regarding students' dietary habits, these were assessed through the KIDMED (Mediterranean Diet Quality Index for children and adolescents), developed by Serra-Majem et al. (2004) [18]. The KIDMED index was developed in an attempt to combine the MD guidelines for adults with the general dietary guidelines for children in a single index. The index comprises 16 yes or no questions, including dietary habits that are in accordance with the principles of the Mediterranean dietary pattern and the general dietary guidelines for youth (e.g. consumption of at least one fruit at a daily basis, consumption of fish 2-3 per week, use of olive oil as the main culinary fat in salad and cooking etc.) and other habits that undermine them (e.g. breakfast skipping, daily consumption of sweets, frequent consumption of fast food etc.). Questions denoting a negative connotation with respect to a high-quality diet are assigned a value of – 1, while those with a positive aspect are assigned a value of + 1. Thus, the total KIDMED score ranges from – 4 to 12 and is classified into three levels: ≥ 8, suggesting an optimal adherence to the MD; 4-7, suggesting an average adherence to the MD and an improvement needed to adjust dietary intake to guidelines; and ≤ 3, suggesting a low adherence to the MD and generally a low diet quality.

### Assessment of self-reported physical activity and sedentary time

With regard to physical activity habits, patterns of physical activity were also self-reported. The questionnaire has been previously used in children in other large-scale epidemiological studies [19], and included simple closed-type questions regarding children's frequency, time and intensity of participation in (i) school-related physical activity (including activity during physical education classes; (ii) organized sports activities and (iii) physical activities during leisure time. For the current analysis, a student's weekly frequency of participation in organized sports activities, physical activities during leisure time and school-related physical activity (range 0-7, i.e. from rare to daily participation), had an average duration (in minutes) per bout of engaging in the above physical activities. The average duration per bout of engaging, if it caused them "to breathe hard or feel tired", (providing a subjective estimation of moderate to vigorous intensity) was calculated. The frequency of all reported activities was multiplied by the minutes of moderate to vigorous physical activities (MVPA) and then divided by seven to obtain the mean daily time children engaged in MVPA. Children who participated in MVPA at least for 60 minutes per day were considered as meeting the recommendation for physical activity [20].

Daily time (in hours) spent in sedentary activities (e.g. television viewing, use of Internet for non-study reasons, playing with computer or/and console games) was also calculated for each student (via multiplying the weekly frequency of participation with the duration per bout of participation in sedentary activities, and then dividing by 7). Using the threshold of two hours per day proposed by current scientific evidence and guidelines [21, 22], students were classified as sedentary or not, i.e., exceeding (> 2 hours per day) or not (≤ 2 hours per day) the recommended daily time spent in sedentary activities.

Moreover, daily time in sleeping hours was assessed through self reported recordings. Based on the Consensus Statement of the American Academy of Sleep Medicine, we classified as meeting the recommendations of sufficient sleep those children (aged 6 to 12-y-old) who were sleeping at least nine hours daily and those adolescents (aged 13 to 17-y-old) who were sleeping at least eight hours per day. Children and adolescents that were sleeping daily fewer than the number of recommended hours were classified as having insufficient sleep [23].

### Ethical approval

Ethical approval for the health survey was graded by the Ethical Review Board of the Ministry of Education and the Ethical Committee of Harokopio University.

### Data analysis

Normality of the distributions regarding continuous variables was verified through the Shapiro-Wilk test, despite the fact that the large sample allows for the assumption of normality of the data. Descriptive statistics of anthropometric measurements were expressed as means ± standard deviations. Prevalence of thinness, normal weight, overweight and obesity was calculated as the ratio of those children belonging in the corresponding class, based on the proposed cut-off points for BMI by IOTF [13, 14] and divided by the total number of children. Comparisons of the prevalence between genders were performed using the Pearson's chi-square test. Furthermore, simple regression analysis was used to evaluate the trends of each anthropometric variable (with lag 0). The independent variable was the year of birth. Serial dependency was evaluated using the partial autocorrelation function; no autocorrelation was observed for various lags tested. Results are presented as b-coefficient ± SE. In order to assess the potential effect of several demographic and lifestyle factors (e.g. age, physical fitness measurements, adherence to Mediterranean diet, sleeping hours, physical activity levels and sedentary activities levels) on the total and central obesity status, binary logistic regression analysis was implemented and odds ratios (OR) with the corresponding 95% confidence intervals (CI) were calculated. The Hosmer and Lemeshow's goodness-of-fit test was calculated in order to evaluate the model's goodness-of-fit and residual analysis was implicated using the dbeta, the leverage, and Cook's distance D statistics in order to identify outliers and influential observations. All other statistical analyses were performed using the SPSS version 23.0 software for Windows (SPSS Inc., Chicago, Il, USA). Statistical significance level from two-sided hypotheses was set at $p < 0.05$.

## Results

### Anthropometric measurements and weight status

Mean values for anthropometric measurements of children and adolescents by age and gender are presented in Table I. Statistically significant differences were incorporated in all anthropometric measurements with boys having higher mean values than their girl peers (all p-values < 0.01), with the exception of WtHR where this was not a stable finding across all age groups. Weight,

**Tab. I.** Anthropometric indices (means ± standard deviation) of population by gender and age.

| | Boys | | | | | | Girls | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age † | N | Height (cm) | Weight (kg) | BMI (kg/m²) | WC (cm) | WHtR | N | Height (cm) | Weight (kg) | BMI (kg/m²) | WC (cm) | WHtR |
| 4 | 3157 | 107.9 (5.0)* | 18.7 (2.8)* | 16.0 (1.9) | 54.8 (4.7) | 0.58 (0.49) | 3091 | 106.6 (5.1) | 18.3 (2.8) | 16.0 (1.9) | 54.5 (4.6) | 0.60 (0.49) |
| 5 | 4550 | 113.1 (5.4)* | 20.8 (3.8)* | 16.3 (2.1)* | 56.6 (5.3)* | 0.48 (0.50) | 4477 | 111.8 (5.3) | 20.2 (3.7) | 16.1 (2.2) | 56.0 (5.4) | 0.49 (0.50) |
| 6 | 11361 | 120.0 (5.6)* | 24.0 (3.7)* | 16.4 (2.4)* | 58.4 (6.3)* | 0.34 (0.47) | 11139 | 118.8 (5.5) | 23.3 (4.6) | 16.4 (2.4) | 57.7 (6.4) | 0.35 (0.48) |
| 7 | 21034 | 125.1 (5.8)* | 26.6 (5.5)* | 16.9 (2.6)* | 59.9 (7.1)* | 0.29 (0.45)* | 21165 | 124.1 (5.8) | 26.0 (5.3) | 16.8 (2.6) | 59.2 (7.2) | 0.30 (0.46) |
| 8 | 21159 | 131.4 (6.0)* | 30.4 (6.7)* | 17.6 (3.0)* | 62.9 (8.2)* | 0.30 (0.46) | 20140 | 130.0 (6.1) | 29.7 (6.5) | 17.4 (3.0) | 62.0 (8.0) | 0.31 (0.46) |
| 9 | 21387 | 136.9 (6.4)* | 34.5 (8.0)* | 18.3 (3.3)* | 65.8 (9.0)* | 0.33 (0.47) | 20524 | 135.6 (6.5) | 33.7 (7.7) | 18.1 (3.2) | 64.7 (8.9) | 0.32 (0.47) |
| 10 | 21162 | 142.1 (6.8)* | 38.5 (9.0)* | 18.9 (3.5)* | 68.6 (9.7)* | 0.35 (0.48)* | 20424 | 141.8 (7.7) | 38.0 (8.9) | 18.7 (3.4) | 67.2 (9.5) | 0.31 (0.46) |
| 11 | 19875 | 147.3 (7.1)* | 43.2 (10.2)* | 19.6 (3.6)* | 71.3 (10.2)* | 0.36 (0.48)* | 18910 | 148.4 (7.6) | 43.0 (9.9) | 19.3 (3.6) | 70.0 (9.8) | 0.30 (0.46) |
| 12 | 16349 | 153.7 (7.9)* | 47.5 (11.3)* | 20.1 (3.8)* | 73.4 (10.5)* | 0.34 (0.47)* | 15465 | 154.8 (7.4) | 47.9 (10.6) | 19.9 (3.6) | 71.5 (10.0) | 0.26 (0.44) |
| 13 | 8515 | 160.5 (8.7)* | 54.0 (12.9)* | 20.7 (3.9)* | 75.5 (10.9)* | 0.28 (0.45)* | 7819 | 159.2 (6.7) | 52.1 (10.8) | 20.5 (3.7) | 72.2 (9.9) | 0.21 (0.41) |
| 14 | 7635 | 167.4 (8.5)* | 60.5 (13.6)* | 21.4 (3.9)* | 77.9 (10.9)* | 0.25 (0.43)* | 6734 | 162.0 (6.2) | 55.6 (10.5) | 21.2 (3.6) | 73.5 (9.8) | 0.20 (0.40) |
| 15 | 6273 | 172.5 (7.5)* | 65.2 (13.1)* | 21.8 (3.8)* | 79.0 (10.7)* | 0.22 (0.41) | 5425 | 163.2 (6.1) | 57.5 (10.2) | 21.6 (3.5) | 74.2 (9.8) | 0.21 (0.40) |
| 16 | 3695 | 175.5 (7.0)* | 69.3 (13.0)* | 22.5 (3.8)* | 80.3 (10.3)* | 0.20 (0.40)* | 3413 | 164.2 (6.3) | 58.9 (10.4) | 21.8 (3.5) | 74.0 (9.3) | 0.20 (0.38) |
| 17 | 2358 | 177.0 (7.1)* | 72.0 (13.2)* | 22.9 (3.7)* | 81.4 (10.8)* | 0.22 (0.41) | 2228 | 164.7 (6.3) | 60.1 (10.8) | 22.1 (3.6) | 74.8 (10.4) | 0.21 (0.40) |
| P for trend | < 0.001 | < 0.001 | < 0.001 | < 0.001 | < 0.001 | | | < 0.001 | < 0.001 | < 0.001 | < 0.001 | |

† = completed age, e.g., 4 years = 4.00-4.99 years; * = p-value < 0.01 between boys and girls; BMI = body mass index; WC = waist circumference; WHtR = waist to height ratio.

height, BMI and waist circumference increased with age in both genders (all p-values for trend < 0.001). In opposite, WtHR presented a relatively decreasing rate with age in boys and girls (p-values for trend < 0.001).

Prevalence of underweight (three grades), normal weight, overweight, and obesity by age and gender, based on IOTF criteria, is incorporated in Table II. In the whole population (4 to 17-y-old), proportions of underweight decreased with age, in both genders (p-values for trend < 0.001). Normal weight boys ranged between 64.3% in 10-y-old and 79.1% in 4-y-old (p-value for trend = 0.137).In girls, the lower proportion (64.4%) incorporated in 9-y-old and the highest in 16-y-old (p-value for trend = 0.031). Overweight boys showed an increasing trend among 4-y and 17-y-old (p = 0.007), while obese girls decreased between the above age range (p-value for trend < 0.001) and presented their lower proportion at the age of 17-y-old. Overweight (including obesity) in boys ranged from 16.2% in 4-y-old to 34.7% in 10-y-old, (p-value for trend = 0.06) while in girls it varied between 19.3% in 17-y-old and 34.0% in 9-y-old (p-value for trend = 0.12). Given that a significant interaction was observed between BMI categories and age (p = 0.01) and additionally individual previous findings in Greece showed that the prevalence of overweight is significantly lower in adolescence in comparison with childhood [3, 10-11, 24], we decided to stratify the analysis in two groups: childhood and adolescent. Analytically, further analysis was performed, splitting the prevalence of BMI categories in two age periods; early/middle childhood (4- to 11-y-old) and adolescence (12- to 17-y-old). Findings regarding the trend of BMI groups by gender during childhood and adolescence are presenting in Table II. During childhood, rates of overweight (including obesity) increased from 16.2% in boys 4-y-old to 34.7% in 11-y-old (p < 0.001) with an increasing trend per 2.7 ± 0.3% (p < 0.001) per year of birth. For girls, an increase in overweight (including obesity) rates from 21.2% in 4-y-old to 34.0% in 9-y-old and 30% in 11-y-old was evident (p < 0.001), with an annual increasing trend equal to 1.58 ± 0.4% (p = 0.005). In opposite, adolescent boys who belong to the overweight (including obesity) group decreased from 33.5% in 12-y-old to 27.9% in 17-y-old (annual rate: – 1.23 ± 0.14%, p = 0.001). Similarly, for adolescent girls, a decrease in overweight (including obesity) rates from 29.6% to 19.3% was evident between 12-y-old and 17-y-old (p = 0.008), with an annual decreasing trend equal to 2.03 ± 0.42% (p = 0.008). In childhood, normal weight and thinness rates were decreasing with age,

**Tab. II.** Prevalence of BMI categories according to IOTF definitions, by gender and age, in 4 to 17- y-old Greek children.

| | Boys | | | | Girls | | | |
|---|---|---|---|---|---|---|---|---|
| Age † | Thinness (%) | Normal weight (%) | Overweight (%) | Obesity (%) | Thinness (%) | Normal weight (%) | Overweight (%) | Obesity (%) |
| **Children** | | | | | | | | |
| 4 | 13,8* | 70,0* | 10,4* | 5,8 | 10,9 | 67,9 | 15,5 | 5,7 |
| 5 | 12,6* | 65,7 | 13,2* | 8,5 | 10,9 | 65,0 | 15,8 | 8,3 |
| 6 | 9,9 | 65,4* | 15,8* | 8,9 | 9,8 | 62,5 | 18,3 | 9,4 |
| 7 | 8,4* | 64,5* | 18,0* | 9,2 | 9,3 | 61,6 | 19,9 | 9,2 |
| 8 | 7,0* | 62,1* | 20,7* | 10,2 | 8,4 | 59,7 | 22,2 | 9,7 |
| 9 | 6,1* | 59,8* | 23,5* | 10,7* | 7,6 | 58,5 | 25,0 | 9,0 |
| 10 | 5,4* | 59,9 | 25,7 | 9,0* | 7,8 | 59,4 | 25,0 | 7,8 |
| 11 | 5,5* | 60,0* | 25,8* | 8,8* | 8,0 | 61,4 | 24,2 | 6,4 |
| B ± SE per year change | − 1.3 ± 0.15 | − 1.4 ± 0.20 | 2.3 ± 0.13 | 0.36 ± 0.19 | − 0.52 ± 0.08 | − 1.0 ± 0.31 | 1.5 ± 0.19 | 0.02 ± 0.24 |
| P for trend < 0.001 | < 0.001 | < 0.001 | = 0.116 | = 0.001 | = 0.014 | < 0.001 | = 0.937 | - |
| **Adolescents** | | | | | | | | |
| 12 | 5,3* | 61,3* | 25,2* | 8,2* | 8,4 | 64,0 | 22,4 | 5,2 |
| 13 | 5,6* | 62,0* | 24,4* | 8,1* | 8,3 | 67,4 | 19,9 | 4,3 |
| 14 | 5,0* | 63,2* | 23,5* | 8,1* | 6,7 | 70,9 | 18,2 | 4,3 |
| 15 | 4,4* | 66,6* | 22,2* | 6,8* | 7,4 | 72,2 | 16,5 | 3,9 |
| 16 | 4,8* | 66,9* | 21,6* | 6,7* | 7,5 | 74,1 | 14,7 | 3,7 |
| 17 | 5,1* | 67,0* | 21,4* | 6,5* | 8,7 | 71,4 | 15,0 | 4,3 |
| B ± SE per year change | − 0.11 ± 0.09 | 1.3 ± 0.23 | − 0.82 ± 0.08 | − 0.40 ± 0.08 | − 0.01 ± 0.20 | 1.7 ± 0.51 | − 1.6 ± 0.20 | − 0.19 ± 0.10 |
| P for trend | = 0.293 | = 0.004 | < 0.001 | = 0.008 | = 0.979 | = 0.031 | = 0.001 | = 0.012 |
| **All** | | | | | | | | |
| B ± SE per year change | − 0.62 ± 0.11 | − 0.05 ± 0.22 | 0.78 ± 0.24 | − 0.22 ± 0.09 | − 0.23 ± 0.06 | 0.78 ± 0.22 | − 0.15± 0.26 | − 0.42 ± 0.10 |
| P for trend | < 0.001 | = 0.137 | = 0.007 | = 0.05 | < 0.001 | = 0.017 | = 0.577 | = 0.001 |

† = completed age, e.g., 4 years = 4.00-4.99 years; * = p-value < 0.05 for differences between boys and girls from the same BMI category.

while rates of normal weight were increasing, in both genders (all p-values for trend < 0.05). In adolescence, normal weight boys and girls were increasing with age, while overweight and obese rates were decreasing, in both genders (all p-values for trend <0.05).

Prevalence of central and total obesity (WtHR ≥ 0.5), by gender and age, are presented in Figures 1, 2. The prevalence of central obesity across age groups follows parallel rates with total obesity (defined according to BMI), with the exception of children aged 4- and 5-y-old. In the whole study population, central obesity was diagnosed in 95.3% and 93.5% of the simple obese boys and girls, respectively (p < 0.001). Additionally, in almost two to three of overweight children (68.6% of boys and 64.3% of girls) coincides with central obesity; while a proportion of 12% of normal weight children were classified as centrally obese. Prevalence of central obesity in the different BMI categories (IOTF definitions) by age and gender is shown in Table III, as well as the secular trends of its development across childhood and adolescence. Moreover, exploring the distribution of total and central obesity by prefecture, we found some extensive areas of high rates, located primarily in the Aegean Sea, Crete and Ionian Sea for both genders.

### Health behaviors of children/adolescents on total/central obesity

Further data analysis was conducted to assess the potential effect of demographic and proximal health behaviors (e.g. age, anthropometric and physical fitness measurements, adherence to the Mediterranean diet, physical and sedentary activity levels, and sleeping hours) on total and central obesity incidence in the whole sample, and in children and adolescents, separately. The initial logistic regression analysis in the whole sample (Table IV) revealed that for every one-year increase in the age the risk of total and central obesity was significantly decreased, while better performances in physical fitness measurements were associated with lower odds of being totally or centrally obese, in both genders. Moreover, compliance with current recommendations in lifestyle factors such as Mediterranean diet, physical activity levels, sleeping hours and sedentary activities seems to decrease odds of being totally or centrally obese, in both genders, with the exception of sleeping hours on centrally obese girls (p = 0.818).

Further analysis (Tab. V) by age groups (e.g. children, adolescents) showed some discrimination in the influence of lifestyle factors on total and central obesity, compared with the whole sample. Specifically, it appears that adequate levels of physical activity did not

Fig. 1. Central obesity (%) by age and gender, in Greek children 4- to 17-y-old.

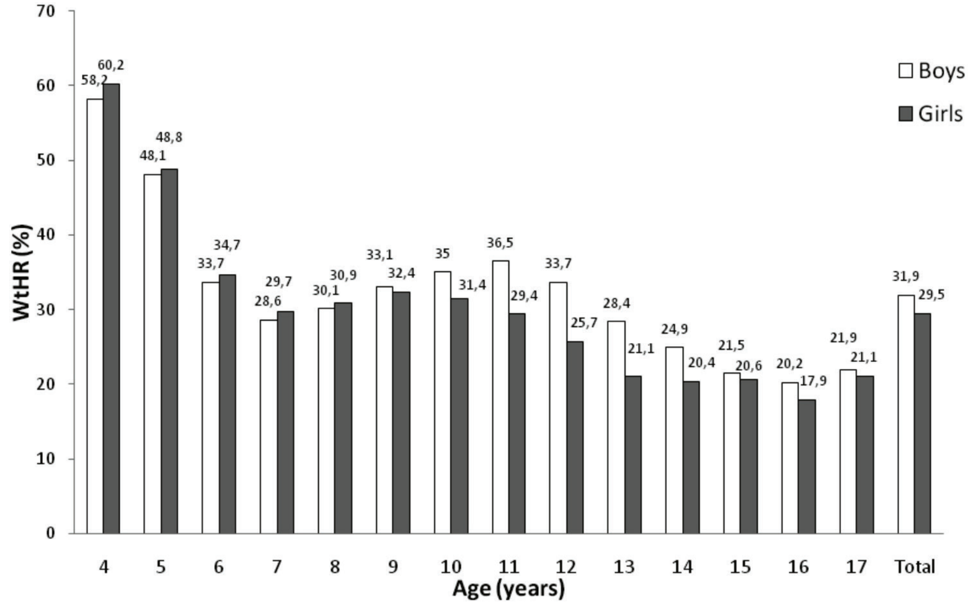
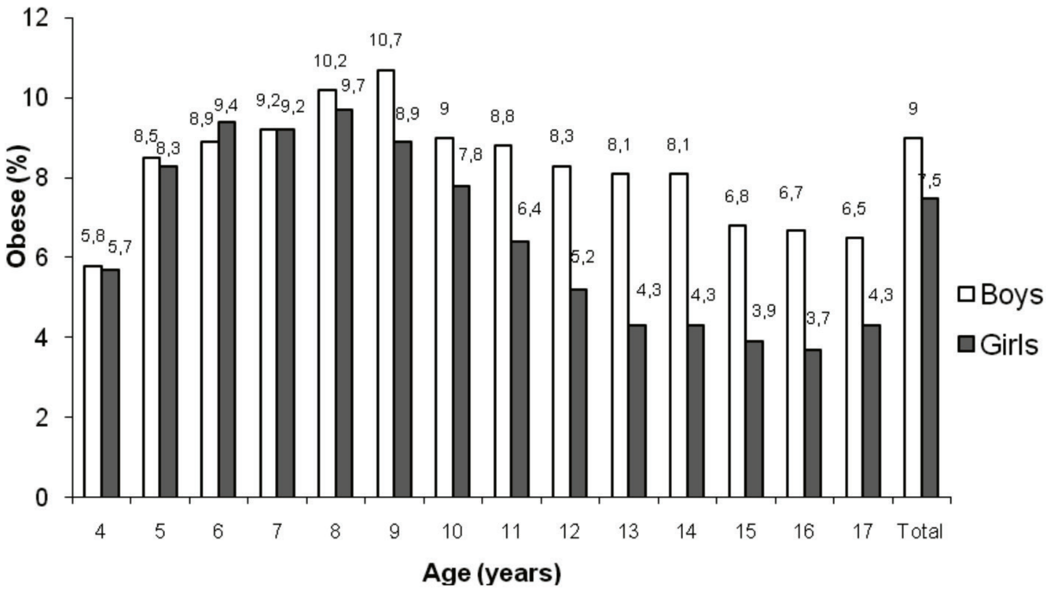



Fig. 2. Total obesity (%) by age and gender, in Greek children 4- to 17-y-old.




have favorable influence on the incidence of total obesity, in children from both sexes. Also, in adolescents of both sexes, increased screen time did not associate with total obesity, while physical activity status and adherence to the Mediterranean diet had not significant effect in total obesity in adolescent boys and girls, respectively. Sleeping hours and physical activity levels of girls aged 4- to 11-y-old did not influence central obesity status. Moreover, in adolescence, physical activity levels in both sexes, screen time in boys and sleeping hours in girls, did not associated with central obesity.

## Discussion

The major findings of our study, based on a epidemiologic, population-based survey indicate that: (a) boys and girls transitioned from childhood to adolescence at more favorable levels of adiposity, (b) central obesity exists in a significant proportion of overweight and normal weight (according to IOTF criteria) children and adolescents and (c) compliance with recommendations in Mediterranean diet, physical activity levels, sleeping hours and sedentary activities decrease the risk of total and central obesity, in both genders.

**Tab. III.** Central obesity (%) by BMI categories (IOTF definitions), gender and age, in 4 to 17-y-old Greek children.

| | Boys * | | | | Girls | | | |
|---|---|---|---|---|---|---|---|---|
| Age † | Total | Normal weight | Overweight | Obesity | Total | Normal weight | Overweight | Obesity |
| **Children** | | | | | | | | |
| 4 | 58.2 | 53.1 | 90.6 | 100 | 60.2 | 52.9 | 93.8 | 97.8 |
| 5 | 48.1 | 38.1 | 83.5 | 97.0 | 48.8 | 37.5 | 84.2 | 98.3 |
| 6 | 33.7 | 19.8 | 68.6 | 92.7 | 34.7 | 19.1 | 68.0 | 93.9 |
| 7 | 28.6 | 12.0 | 62.7 | 94.2 | 29.7 | 13.0 | 61.0 | 92.5 |
| 8 | 30.3 | 10.1 | 66.2 | 94.9 | 30.9 | 11.2 | 65.2 | 92.1 |
| 9 | 33.1 | 10.0 | 69.7 | 95.8 | 32.4 | 11.6 | 66.3 | 94.7 |
| 10 | 35.0 | 11.1 | 74.1 | 96.2 | 31.4 | 11.0 | 67.2 | 94.8 |
| 11 | 36.5 | 12.4 | 77.5 | 96.5 | 29.4 | 11.1 | 65.3 | 93.6 |
| B ± SE per year change | − 2.6 ± 1.3 | − 5.4 ± 1.5 | − 1.6 ± 1.4 | − 0.22 ± 0.35 | − 3.7 ± 1.1 | − 5.4 ± 1.5 | − 3.4 ± 1.3 | − 0.54 ± 0.30 |
| P for trend | = 0.095 | = 0.013 | = 0.312 | = 0.551 | = 0.017 | = 0.011 | = 0.039 | = 0.134 |
| **Adolescents** | | | | | | | | |
| 12 | 33.7 | 11.3 | 73.7 | 95.7 | 25.7 | 9.7 | 62.0 | 92.8 |
| 13 | 28.4 | 8.0 | 63.0 | 94.5 | 21.1 | 8.0 | 55.4 | 92.8 |
| 14 | 24.9 | 5.9 | 55.9 | 95.3 | 20.4 | 8.5 | 55.0 | 90.6 |
| 15 | 21.5 | 5.3 | 51.2 | 93.8 | 20.6 | 9.6 | 56.6 | 93.3 |
| 16 | 20.2 | 4.7 | 48.9 | 94.6 | 17.9 | 8.2 | 53.2 | 92.9 |
| 17 | 21.9 | 5.7 | 53.3 | 96.6 | 21.1 | 9.9 | 58.6 | 90.0 |
| B ± SE per year change | − 2.5 ± 0.6 | − 1.1 ± 0.4 | − 4.3 ± 1.2 | 0.09 ± 0.26 | − 0.93 ± 0.5 | 0.08 ± 0.22 | − 0.63 ± 0.77 | − 0.31 ± 0.34 |
| P for trend | = 0.013 | = 0.039 | = 0.027 | = 0.360 | = 0.135 | = 0.746 | = 0.46 | = 0.40 |

† = completed age, e.g., 4 years = 4.00–4.99 years; * = p-value < 0.05 for differences between boys and girls from the same BMI category; the prevalence of abdominal obesity differs significantly between categories of BMI categories in both genders.

To update country data on childhood obesity and evaluate public health interventions, the EYZHN (National Action for Children's Health) program analyzed anthropometric, physical fitness measurements and several lifestyle factors for public and private schoolchildren in pre-elementary to middle school (4- to 17-y-old), using data from about 360,000 boys and girls.

Our study has several strengths. It was conducted in a wide age-range group and examined several anthropometric and lifestyle factors. Moreover, childhood is doubtless an advantageous period to apply effective obesity prevention strategies. At adolescence, physiological (e.g. pubertal stage) and behavioral (e.g. eating disorders, established dietary habits) factors may hold back prevention efforts. A second advantage of the presented data is that it is derived using the same standardized procedure of measurements and are based on almost all the child and adolescent population of Greece. Furthermore, the use of the IOTF cut-off points for BMI classification for thinness, normal-weight [13], overweight, and the obese [14], are the most proper for large epidemiological studies [15] and allow for direct comparisons of our results with those from other countries. Finally, primary and secondary education is compulsory in Greece and, therefore, we were able to study a great proportion of 4- to 17-y-old children and adolescents. The later overcomes the methodological flaws of previous studies performed in Greece that were heterogeneous in terms of design, target- population, quality, theoretical underpinning and outcome measures [9-12, 24], making impractical to compare study findings with the data from other similar projects.

Data from our representative sample of 4- to 17-y-old Greek children and adolescents indicate that the overall prevalence of obesity was higher in boys (9.0%) than in girls (7.5%), ($p < 0.001$). The overall rate of overweight was 22.2% in boys and 21.6% in girls. The prevalence of overweight children was higher in girls younger than 9-y-old, compared to boys, while the proportion of obese girls was elevated in comparison with boys only in 6-y-old and decreasing thereafter. Our findings regarding prevalence of overweight and obesity are consistent with previous data from different regions of Greece [4, 10-12, 24-25]. According to the WHO European Region, prevalence of childhood overweight (including obesity) varied significantly among European countries, ranged from 11% to 33%, with highest rates in Southern European countries (i.e. Greece 33%). In adolescence, prevalence of overweight (including obesity) ranged from 10% (i.e. the Russian Federation) to 23% (Greece) [26]. This study confirms the above notion and suggests that additional actions should be adopted for the treatment of obesity in our country.

Boys and girls transitioned from childhood to adolescence had more favorable levels of overweight and obesity (total and central). Nevertheless, the reductions are less pronounced with girls compared with all children. Probably, dieting with advanced age, especially in girls,

**Tab. IV.** Associations between demographic and health behaviours and unadjusted odds of total and central obesity, by gender.

| Predictors | Total obesity OR (95% CI) | P-value | Central obesity OR (95% CI) | P-value |
|---|---|---|---|---|
| **Boys** | | | | |
| Age (per 1 year) | 0.972 (0.966-0.978) | < 0.001 | 0.958 (0.955-0.962) | < 0.001 |
| Waist circumference (per 1 cm) | 1.136 (1.134-1.038) | < 0.001 | - | - |
| Weight (per 1 kg) | - | - | 1.036 (1.036-1.037) | < 0.001 |
| Sit and reach test (per 1cm) | 0.918 (0.915-0.920) | < 0.001 | 0.976 (0.974-0.977) | < 0.001 |
| 20 meters shuttle run test (per 1 stage) | 0.931 (0.929-0.933) | < 0.001 | 0.955 (0.955-0.956) | < 0.001 |
| 10 x 5 meters shuttle run test (per 1 sec) | 1.099 (1.094-1.103) | < 0.001 | 1.097 (1.094-1.101) | < 0.001 |
| Sit-ups in 30 seconds (per 1 sit-up) | 0.918 (0.915-0.920) | < 0.001 | 0.941 (0.940-0.943) | < 0.001 |
| Standing long jump (per 1 cm) | 0.995 (0.995-0.995) | < 0.001 | 0.996 (0.996-0.996) | < 0.001 |
| Adherence to the Mediterranean diet (moderate/high vs low) | 1.152 (1.087-1.212) | < 0.001 | 1.050 (1.002-1.092) | = 0.044 |
| Sleeping hours (sufficient vs insufficient) | 1.225 (1.168-1.286) | < 0.001 | 1.143 (1.109-1.177) | < 0.001 |
| Screen time (acceptable vs increased time) | 1.184 (1.123-1.247) | < 0.001 | 1.054 (1.020-1.099) | = 0.002 |
| Physical activity levels (adequate vs inadequate) | 1.037 (1.004-1.066) | = 0.034 | 1.035 (1.005-1.067) | = 0.023 |
| **Girls** | | | | |
| Age (per 1 year) | 0.908 (0.901-0.914) | < 0.001 | 0.920 (0.917-0.924) | <0.001 |
| Waist circumference (per 1 cm) | 1.136 (1.133-1.038) | < 0.001 | - | - |
| Weight (per 1 kg) | - | - | 1.035 (1.034-1.036) | < 0.001 |
| Sit and reach test (per 1 cm) | 0.907 (0.904-0.910) | < 0.001 | 0.975 (0.973-0.977) | < 0.001 |
| 20 meters shuttle run test (per 1 stage) | 0.902 (0.899-0.905) | < 0.001 | 0.945 (0.943-0.946) | < 0.001 |
| 10 x 5 meters shuttle run test (per 1 sec) | 1.098 (1.093-1.103) | < 0.001 | 1.096 (1.092-1.100) | < 0.001 |
| Sit-ups in 30 seconds (per 1 sit up) | 0.907 (0.904-0.920) | < 0.001 | 0.939 (0.937-0.940) | < 0.001 |
| Standing long jump (per 1 cm) | 0.995 (0.995-0.996) | < 0.001 | 0.996 (0.996-0.996) | < 0.001 |
| Adherence to the Mediterranean diet (moderate/high vs low) | 1.120 (1.039-1.199) | = 0.006 | 1.069 (1.020-1.116) | = 0.008 |
| Sleeping hours (sufficient vs insufficient) | 1.102 (1.064-1.167) | = 0.001 | 0.996 (0.964-1.029) | 0.818 |
| Screen time (acceptable vs increased time) | 1.155 (1.081-1.233) | < 0.001 | 1.086 (1.046-1.128) | < 0.001 |
| Physical activity levels (adequate vs inadequate) | 1.104 (1.046-1.166) | < 0.001 | 1.066 (1.034-1.098) | < 0.001 |

could be an explanation for the reduction in overweight and obesity after 11 years of age. In fact, study from Yiannakoulia et al., (2004) found that the proportion of Greek girls reporting to be on a diet to lose weight was rising with age (from 11.5- to 15.5-y-old) [27]. The finding that overweight and obesity in boys and girls are declining across age has been reported in Greece and elsewhere [4, 5]. The fact that overweight and obesity were higher in the younger ages reveals that further targeted actions should be focused in these age groups.

Regarding thinness, there is little information in European children and no data from Greece. The prevalence of thinness in the present study is quite similar to that reported from other European countries. Specifical-

Table V. Associations between demographic and health behaviours and unadjusted odds of total and central obesity in children and adolescents, by gender.

| | Total obesity OR (95% CI) | | | | Central obesity OR (95% CI) | | | |
|---|---|---|---|---|---|---|---|---|
| | Children | | Adolescents | | Children | | Adolescents | |
| **Boys** | | | | | | | | |
| Age (per 1 year) | 0.977 (0.968-0.987) | < 0.001 | 0.936 (0.905-0.968) | < 0.001 | 1.044 (1.038-1.051) | < 0.001 | 0.898 (0.879-0.917) | < 0.001 |
| Waist circumference (per 1 cm) | 1.177 (1.175-1.180) | < 0.001 | 1.248 (1.239-1.258) | < 0.001 | - | - | - | - |
| Weight (per 1 kg) | - | - | - | - | 1.103 (1.102-1.105) | < 0.001 | 1.248 (1.239-1.258) | < 0.001 |
| Sit and reach test (per 1cm) | 0.980 (0.977-0.993) | < 0.001 | 0.982 (0.977-0.985) | < 0.001 | 0.976 (0.975-0.978) | < 0.001 | 0.978 (0.974-0.981) | < 0.001 |
| 20 meters shuttle run test (per 1 stage) | 0.924 (0.922-0.926) | < 0.001 | 0.941 (0.937-0.945) | < 0.001 | 0.954 (0.953-0.955) | < 0.001 | 0.956 (0.954-0.958) | < 0.001 |
| 10 x 5 meters shuttle run test (per 1 sec) | 1.097 (1.092-1.102) | < 0.001 | 1.109 (1.097-1.120) | < 0.001 | 1.087 (1.084-1.091) | < 0.001 | 1.123 (1.113-1.133) | < 0.001 |
| Sit-ups in 30 seconds (per 1 sit-up) | 0.919 (0.916-0.922) | < 0.001 | 0.877 (0.870-0.884) | < 0.001 | 0.950 (0.948-0.952) | < 0.001 | 0.895 (0.890-0.900) | < 0.001 |
| Standing long jump (per 1 cm) | 0.995 (0.994-0.995) | < 0.001 | 0.996 (0.996-0.997) | < 0.001 | 0.996 (0.996-0.996) | < 0.001 | 0.997 (0.996-0.997) | < 0.001 |
| Adherence to Mediterranean diet (moderate/high vs low) | 1.166 (1.089-1.237) | < 0.001 | 1.186 (1.067-1.290) | = 0.003 | 1.089 (1.036-1.139) | = 0.001 | 1.100 (1.018-1.176) | = 0.018 |
| Sleeping hours (sufficient vs insufficient) | 1.191 (1.128-1.258) | < 0.001 | 1.315 (1.186-1.457) | < 0.001 | 1.136 (1.098-1.175) | < 0.001 | 1.090 (1.061-1.124) | = 0.010 |
| Screen time (acceptable vs increased time) | 1.263 (1.188-1.343) | < 0.001 | 1.103 (0.994-1.224) | = 0.064 | 1.151 (1.107-1.196) | < 0.001 | 1.040 (0.975-1.110) | = 0.229 |
| Physical activity levels (adequate vs inadequate) | 1.049 (0.991-1.109) | = 0.097 | 0.982 (0.886-1.088) | = 0.728 | 1.043 (1.008-1.080) | = 0.016 | 0.970 (0.911-1.034) | = 0.354 |
| **Girls** | | | | | | | | |
| Age (per 1 year) | 0.903 (0.893-0.913) | < 0.001 | 0.994 (0.949-1.040) | = 0.783 | 0.961 (0.955-0.968) | < 0.001 | 0.988 (0.966-1.011) | = 0.315 |
| Waist circumference (per 1 cm) | 1.163 (1.160-1.166) | < 0.001 | 1.230 (1.219-1.241) | < 0.001 | - | - | - | - |
| Weight (per 1 kg) | - | - | - | - | 1.030 (1.023-1.037) | < 0.001 | 1.073 (1.072-1.074) | < 0.001 |
| Sit and reach test (per 1 cm) | 0.983 (0.980-0.985) | < 0.001 | 0.980 (0.973-0.987) | < 0.001 | 0.977 (0.975-0.979) | < 0.001 | 0.978 (0.974-0.981) | < 0.001 |
| 20 meters shuttle run test (per 1 stage) | 0.903 (0.900-0.907) | < 0.001 | 0.905 (0.894-0.915) | < 0.001 | 0.943 (0.942-0.945) | < 0.001 | 0.961 (0.957-0.964) | < 0.001 |
| 10 x 5 meters shuttle run test (per 1 sec) | 1.092 (1.087-1.098) | < 0.001 | 1.099 (1.086-1.113) | < 0.001 | 1.088 (1.084-1.092) | < 0.001 | 1.099 (1.089-1.110) | < 0.001 |
| Sit-ups in 30 seconds (per 1 sit up) | 0.913 (0.910-0.917) | < 0.001 | 0.884 (0.873-0.895) | < 0.001 | 0.945 (0.943-0.947) | < 0.001 | 0.922 (0.916-0.928) | < 0.001 |
| Standing long jump (per 1 cm) | 0.994 (0.994-0.995) | < 0.001 | 0.996 (0.996-0.997) | < 0.001 | 0.995 (0.995-0.996) | < 0.001 | 0.997 (0.997-0.998) | < 0.001 |
| Adherence to Mediterranean diet (low vs moderate/high) | 1.229 (1.143-1.306) | < 0.001 | 1.095 (0.923-1.247) | = 0.284 | 1.159 (1.103-1.211) | < 0.001 | 1.124 (1.039-1.202) | = 0.005 |
| Sleeping hours (sufficient vs insufficient) | 1.114 (1.045-1.187) | < 0.001 | 1.241 (1.082-1.223) | = 0.002 | 1.022 (0.985-1.060) | = 0.250 | 1.030 (0.960-1.105) | = 0.405 |
| Screen time (acceptable vs increased time) | 1.319 (1.223-1.422) | < 0.001 | 1.125 (0.975-1.428) | = 0.108 | 1.224 (1.169-1.280) | < 0.001 | 1.134 (1.055-1.129) | = 0.001 |
| Physical activity levels (adequate vs inadequate) | 1.038 (0.988-1.102) | = 0.220 | 1.157 (1.009-1.326) | = 0.036 | 1.012 (0.977-1.047) | = 0.487 | 1.059 (0.988-1.134) | = 0.106 |

ly, Boddy et al., 2008 [28], Martinez-Vizcaino et al., 2015 [29], and Lazzeri et al., 2008 [30] have reported overall prevalence of thinness ranging from 6.2% to 9.5% and found significantly higher prevalence in girls, a finding similar to ours. Furthermore, results in children and adolescents from 10 European countries and the USA are in accordance with our findings and proposed that girls and younger children presented higher prevalence of thinness compared to boys and older ones, respectively [31].

Waist to Height ratio has emerged as a central adiposity parameter and significant predictor of risk factors for cardiovascular disease in children and adolescents [9]. We assessed the prevalence of central obesity throughout childhood and adolescence and we specifically focused on its presence in normal weight and overweight children. Our findings proposed that boys were more likely to be centrally obese than girls (31.9% vs 29.5%, $p < 0.001$), and in line with current evidences from nationwide Greek survey of children and adolescents, based on WHtR measurements [19, 32]. On the contrary, a review of 29 studies by de Moraes et al., (2011) incorporate that is not clear what gender has a higher proportion [33]. In the total study population, 30% of children were centrally obese while almost two to three of overweight children and 12% of normal weight were classified as centrally obese. Central obesity rates in Greek children and adolescents are higher than those have reported in Swedish, English and Spanish children and adolescents [34-36], but quite similar to that incorporated from the USA [37] and Greece [11, 19]. In our study, prevalence of central obesity in children 4- to 5-y-old was remarkably high (48 to 60%). Although, a value of 0.5 in WtHR indicates high sensitivity and specificity to detect obesity in individuals aged 6-18 years, results from a study of 5,725 Norwegian children and adolescents recommended that in younger children, this cutoff was not appropriate due to low specificity [38]. Moreover, according to Taylor et al., (2011), due to the residual correlation between WtHR and stature in children, the division of WC by height may be insufficient to properly adjust the height during growth [39]. Evidences from the Bogolusa Heart Study highlighted that normal weight and overweight children with central obesity had increased cardio-metabolic risk in comparison with overweight children without excessive abdominal fat [40]. Those findings, especially in Greece, are of particular concern because the simultaneous presentation of total and central obesity may demand specific intervention programs against abdominal fat accumulation.

To our knowledge this study is the first to examine the association of obesity with several modifiable lifestyle factors simultaneously, in a representative sample of 6-to 17-y-old boys and girls. Adherence to the Mediterranean diet, physical and sedentary activity levels, and physical fitness measurements associated with the risk of being obese (total or/and central) among Greek children and adolescents. The present study reveals that excess body weight was negatively associated with physical fitness in children and adolescents, a finding that is in line with other studies supporting that obese children are not physically fit [41, 42]. The most obvious explanation is that excess weight is a disadvantageous parameter for performance, particularly for weight-bearing activities like running and jumping.

Nationally representative European studies collecting data with the use of a common data protocol on physical activity and nutrition habits, are limited. Specifically, the HBSC study targeting 11-, 13- and 15-y-old [43], the ENERGY study targeting 10/12-y-old [44] and the WHO European COSI study in 6 to 9-y-old children [45]. Our findings in the whole study group support the notion that adherence to Mediterranean diet, adequate physical activity levels, sufficient sleeping hours and acceptable screen time decrease the risk of total and central obesity, in both genders. In line with us, the HBSC study supported a strong and consistent negative association of overweight with dietary habits and physical activity, while the ENERGY study concluded that appropriate dietary behaviors, lack of physical activity and sedentary behaviors are regarded as potential risk factors for becoming overweight/obese [43, 44]. Furthermore, the COSI study in 6- to 9-y-old children from five countries speculated that unhealthy eating behaviors and spending screen time ≥ 2 h/d were positively associated with obesity [45]. In our study, no consistent relations (in children and adolescents) between adequate physical activity levels and total and/or central obesity were noted. Nevertheless, we did not find related studies to compare with for the associations of adequate physical activity with total and central obesity, in children and adolescents, separately.

Limitations of the present study include some methodological issues, and the fact that potential confounding factors, such as sexual maturation, genetic predisposition to obesity etc., have not been evaluated. Dietary habits, physical activity and sedentary time status are based on self-reported data that could be subject to socially desirable reporting bias. However, children responses were anonymous; therefore, participants had no reason to dissemble or misreport their answers. Moreover, although a standard protocol was used to measure anthropometric data, the large number of professionals that have participated as evaluators, may have introduced inter-observer measurement error. Finally, because of the large sample size, statistical significance can easily be achieved.

## Conclusions

Despite the aforementioned limitations, this is the first study that reports on the most recent total and central obesity prevalence trends in Greek children and adolescents 4- to 17-y-old. Results revealed that total obesity and overweight rates of both sexes are alarmingly elevated while central obesity coexists in the most overweight and obese children and adolescents. An encouraging finding of our data was that obesity presented decreasing trends in the transition from childhood to adolescence. Finally, it seems that low physical fitness, low adherence to Mediterranean diet, insufficient sleeping hours, inadequate physical activity levels and increased screen time constitute risk factors of obesity since all are associated with higher odds of total and central obesity. Serious and urgent actions need to be taken from public health policy makers affecting both social and market environment in order not only to prevent a further increase in overweight and obesity rates but, more importantly, to treat obesity and/or the obesity associated co-morbidities.

## Acknowledgements

This study was supported by the Hellenic Ministry of Education and Religious Affairs, Secretariat General of Sports, OPAP S.A., Nestlé Hellas S.A., and the Department of Nutrition and Dietetics Graduate Program, Harokopio University of Athens. We thank Mr Art Berke for language editing, and proofreading.
The authors declare that there is no conflict of interest.

## Authors' contributions

KDT designed the study, performed the data collection and analysis and wrote the paper. DBP and GP participated in the design of the study and critically reviewed the paper. LSS was involved in the study design, manuscript writing and in overall supervision of the study.

### References

[1] James WP. The epidemiology of obesity: the size of the problem. J Intern Med 2008;263(6):336-52. doi: 10.1038/ijo.2008.247.

[2] Kosti RI, Panagiotakos DB. The epidemic of obesity in children and adolescents in the world. Cent Eur J Public Health 2006; 14(4):151-9.

[3] Tambalis KD, Panagiotakos DB, Kavouras SA, Kallistratos AA, Moraiti IP, Douvis SJ, Toutouzas PK, Sidossis LS. Eleven-year prevalence trends of obesity in Greek children: first evidence that prevalence of obesity is leveling off. Obesity (Silver Spring) 2010; 18(1):161-6. doi: 10.1038/oby.2009.188.

[4] Kleanthous K, Dermitzaki E, Papadimitriou DT, Papaevangelou V, Papadimitriou A. Overweight and obesity decreased in Greek schoolchildren from 2009 to 2012 during the early phase of the economic crisis. Acta Paediatr 2016;105(2):200-5. doi: 10.1111/apa.13143.

[5] Koebnick C, Mohan YD, Li X, Young DR. Secular trends of overweight and obesity in young Southern Californians 2008-2013. J Pediatr 2015;167(6):1264-71. doi: 10.1016/j.jpeds.2015.08.039.

[6] Williams J, Wake M, Hesketh K, Maher E, Waters E. Health-related quality of life of overweight and obese children. JAMA 2005;293(1):70-6. doi: 10.1001/jama.293.1.70

[7] Reilly JJ, Methven E, McDowell ZC, Hacking B, Alexander D, Stewart L, Kelnar CJ. Health consequences of obesity. Arch Dis Child 2003;88(9):748-52. doi: 10.1136/adc.88.9.748.

[8] Després JP, Lemieux I, Bergeron J, Pibarot P, Mathieu P, Larose E, Rodés-Cabau J, Bertrand OF, Poirier P. Abdominal obesity and the metabolic syndrome: Contribution to global cardiometabolic risk. Arterioscler Thromb Vasc Biol 2008(6);28:1039-49. doi: 10.1161/ATVBAHA.107.159228.

[9] Savva SC, Tornaritis M, Savva ME, Kourides Y, Panagi A, Silikiotou N, Georgiou C, Kafatos A. 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(11):1453-8.

[10] Grammatikopoulou MG, Poulimeneas D, Gounitsioti IS, Gerothanasi K, Tsigga M, Kiranas E; ADONUT Study Group. Prevalence of simple and abdominal obesity in Greek adolescents: the ADONUT study. Clin Obes 2014;4(6):303-8. doi: 10.1111/cob.12070.

[11] Hassapidou M, Tzotzas T, Makri E, Pagkalos I, Kaklamanos I, Kapantais E, Abrahamian A, Polymeris A, Tziomalos K. Prevalence and geographic variation of abdominal obesity in 7- and 9-year-old children in Greece; World Health Organization Childhood Obesity Surveillance Initiative 2010. BMC Public Health 2017;17(1):126. doi: 10.1186/s12889-017-4061-x.

[12] Hassapidou M, Daskalou E, Tsofliou F, Tziomalos K, Paschaleri A, Pagkalos I, Tzotzas T. Prevalence of overweight and obesity in preschool children in Thessaloniki, Greece. Hormones (Athens) 2015;14(4):615-22. doi: 10.14310/horm.2002.1601.

[13] Cole T, Flegal K, Nicholls D, Jackson A. "Body mass index cut offs to define thinness in children and adolescents: international survey." BMJ 2007;335(7612):194--8. doi: 10.1136/bmj.39238.399444.55.

[14] Cole T, Bellizzi M, Flegal K, Dietz W. Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ 2000;320(7244):1240-3.

[15] World Health Organization (WHO). Physical Status: the use and interpretation of anthropometry: Tech Rep Series 854, 1995. Geneva: WHO.

[16] Browning LM, Hsieh SD, Ashwell M. A systematic review of waist-to-height ratio as a screening tool for the prediction of cardiovascular disease and diabetes: 0.5 could be a suitable global boundary value. Nutr Res Rev 2010; 23(2):247-69. doi: 10.1017/S0954422410000144.

[17] Council of Europe Committee of Experts on Sports Research (1993) Eurofit: handbook for the Eurofit tests of Physical fitness. 1-75.

[18] Serra-Majem L, Ribas L, Ngo J, Ortega RM, García A, Pérez-Rodrigo C, Aranceta J. Food, youth and the Mediterranean diet in Spain. Development of KIDMED, Mediterranean Diet Quality Index in children and adolescents. Public Health Nutrition 2004;7(7):931-5. doi: 10.1079/PHN2004556.

[19] Grigorakis DA, Georgoulis M, Psarra G, Tambalis KD, Panagiotakos DB, Sidossis LS. Prevalence and lifestyle determinants of central obesity in children. Eur J Nutr 2016;55(5):1923-31. doi: 10.1007/s00394-015-1008-9.

[20] World Health Organization (WHO). Global Recommendations on Physical Activity for Health. Geneva, World Health Organization, 2010.http://whqlibdoc.who.int/publications/2010/9789241599979_eng.pdf. Accessed on 10/05/2017.

[21] Colley RC, Janssen I, Tremblay MS. Daily step target to measure adherence to physical activity guidelines in children. Med Sci Sports Exerc 2012;44(5):977-82. doi: 10.1249/MSS.0b013e31823f23b1.

[22] Tremblay MS, Leblanc AG, Janssen I, Kho ME, Hicks A, Murumets K, Colley RC, Duggan M. Canadian sedentary behaviour guidelines for children and youth. Appl Physiol Nutr Metab 2011;36(1):59-64. doi: 10.1139/H11-012.

[23] Paruthi S, Brooks LJ, D'Ambrosio C, Hall WA, Kotagal S, Lloyd RM, Malow BA, Maski K, Nichols C, Quan SF, Rosen CL, Troester MM, Wise MS. Consensus Statement of the American Academy of Sleep Medicine on the Recommended Amount of Sleep for Healthy Children: Methodology and Discussion. J Clin Sleep Med. 2016; 12(11):1549-1561. doi: 10.5664/jcsm.6288.

[24] Patsopoulou A, Tsimtsiou Z, Katsioulis A, Rachiotis G, Malissiova E, Hadjichristodoulou C. Prevalence and risk factors of overweight and obesity among adolescents and their parents in Central Greece (FETA Project). Int J Environ Res Public Health 2015;13(1):83. doi: 10.3390/ijerph13010083.

[25] Georgiadis G, Nassis GP. Prevalence of overweight and obesity in a national representative sample of Greek children and adolescents. Eur J Clin Nutr 2007;61(9):1072-4. doi: 10.1038/sj.ejcn.1602619.

[26] http://www.euro.who.int/__data/assets/pdf_file/0004/243337/Summary-document-53-MS-country-profile.pdf?ua=1. Assessed on 11/06/2017.

[27] Yannakoulia M, Karayiannis D, Terzidou M, Kokkevi A, Sidossis LS. Nutrition-related habits of Greek adolescents. Eur J Clin Nutr. 2004;58(4):580-6. doi: 10.1038/sj.ejcn.1601849.

[28] Boddy LM, Hackett AF, Stratton G. The prevalence of underweight in 9- and 10-year-old schoolchildren in Liverpool: 1998-2006. Public Health Nutr 2009;12(7):953-6. doi: 10.1017/S136898000800311X.

[29] Martínez-Vizcaíno V, Solera-Martínez M, Cavero-Redondo I, García-Prieto JC, Arias-Palencia N, Notario-Pacheco B, Martínez-Andrés M, Mota J, Sánchez-López M; Cuenca Study Group. Association between parental socioeconomic status with underweight and obesity in children from two Spanish birth cohorts: a changing relationship. BMC Public Health 2015;15:1276.doi: 10.1186/s12889-015-2569-5.

[30] Lazzeri G, Rossi S, Pammolli A, Pilato V, Pozzi T, Giacchi MV. Underweight and overweight among children and adolescents in Tuscany (Italy). Prevalence and short-term trends. J Prev Med Hyg. 2008; 49(1):13-21.

[31] Lazzeri G, Rossi S, Kelly C, Vereecken C, Ahluwalia N, Giacchi MV. Trends in thinness prevalence among adolescents in ten European countries and the USA (1998-2006): a cross-sectional survey. Public Health Nutr 2014;17(10):2207-15. doi: 10.1017/S1368980013002541.

[32] Tzotzas T, Kapantais E, Tziomalos K, Ioannidis I, Mortoglou A, Bakatselos S, Kaklamanou M, Lanaras L, Kaklamanou D. Prevalence of overweight and abdominal obesity in Greek children 6-12 years old: Results from the National Epidemiological Survey. Hippokratia 2011; 15(1): 48–53.

[33] de Moraes AC, Fadoni RP, Ricardi LM, Souza TC, Rosaneli CF, Nakashima AT, Falcão MC. Prevalence of abdominal obesity in adolescents: a systematic review. Obes Rev 2011;12(2):69-77. doi: 10.1111/j.1467-789X.2010.00753.x.

[34] 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) 2004; 30(6):988-92. doi: 10.1038/sj.ijo.0803226.

[35] Ortega FB, Ruiz JR, Vicente-Rodríguez G, Sjöström M. Central adiposity in 9- and 15-year-old Swedish children from the European Youth Heart Study. Int J Pediatr Obes 2008;3(4):212-6. doi: 10.1080/17477160802068965.

[36] Schröder H, Ribas L, Koebnick C, Funtikova A, Gomez SF, Fíto M, Perez-Rodrigo C, Serra-Majem L. Prevalence of abdominal obesity in Spanish children and adolescents. Do we Need Waist Circumference Measurements in Pediatric Practice? PLoS One 2014;27;9(1):e87549. doi: 10.1371/journal.pone.0087549.

[37] Li C, Ford ES, Mokdad AH, Cook S. Recent trends in waist circumference and waist-height ratio among US children and adolescents. Pediatrics 2006;118(5):e1390-8. doi: 10.1542/peds.2006-1062.

[38] Brannsether B, Roelants M, Bjerknes R, Júlíusson PB. Waist circumference and waist-to-height ratio in Norwegian children 4-18 years of age: reference values and cut-off levels. Acta Paediatr 2011;100(12):1576-82. doi: 10.1111/j.1651-2227.2011.02370.x.

[39] Taylor RW, Williams SM, Grant AM, Taylor BJ, Goulding A. Predictive ability of waist-to-height in relation to adiposity in children is not improved with age and sex-specific values. Obesity (Silver Spring) 2011;19(5):1062-8. doi: 10.1038/oby.2010.217.

[40] Mokha JS, Srinivasan SR, Dasmahapatra P, Fernandez C, Chen W, Xu J, Berenson GS. Utility of waist-to-height ratio in assessing the status of central obesity and related cardiometabolic risk profile among normal weight and overweight/obese children: the Bogalusa Heart Study. BMC Pediatr 2010;10:73. doi: 10.1186/1471-2431-10-73.

[41] Sacchetti R, Ceciliani A, Garulli A, Masotti A, Poletti G, Beltrami P, Leoni E. Physical fitness of primary school children in relation to overweight prevalence and physical activity habits. J Sports Sci 2012;30(7):633-40. doi: 10.1080/02640414.2012.661070.

[42] Tambalis KD, Panagiotakos DB, Arnaoutis G, Sidossis LS. Endurance, explosive power and muscle strength in relation to Body Mass Index and physical fitness in Greek children aged 7 to 10-y-old. Pediatric Exercise Science 2013;25(3):394-406.

[43] Dupuy M, Godeau E, Vignes C, Ahluwalia N. Socio-demographic and lifestyle factors associated with overweight in a representative sample of 11 to 15-year-old in France: results from the WHO-Collaborative Health Behaviour in School-aged Children (HBSC) cross-sectional study. BMC Public Health 2011;11:442. doi: 10.1186/1471-2458-11-442.

[44] Brug J, van Stralen MM, teVelde SJ, Chinapaw MJ, De Bourdeaudhuij I, Lien N, Bere E, Maskini V, Singh AS, Maes L, Moreno L, Jan N, Kovacs E, Lobstein T, Manios Y. Differences in weight status and energy-balance related behaviours among schoolchildren across Europe: the ENERGY-project. PLoS One 2012;7:e34742. doi: 10.1371/journal.pone.0034742.

[45] Wijnhoven TM, van Raaij JM, Yngve A, Sjöberg A, Kunešová M, Duleva V, Petrauskiene A, Rito AI, Breda J. WHO European Childhood Obesity Surveillance Initiative: health-risk behaviours on nutrition and physical activity in 6-9-year-old schoolchildren. Public Health Nutr 2015;18(17):3108-24. doi: 10.1017/S1368980015001937.

■ Received on June 24, 2017. Accepted on January 29, 2018.

■ Correspondence: Labros S. Sidossis, Department of Kinesiology and Health, 70 Lipman Drive, New Brunswick, NJ 08901-8525. Tel. 848-932-9512 - E-mail: lsidossis@kines.rutgers.edu