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ORIGINAL ARTICLE

Twenty-year dynamics in adiposity and blood lipids of Greek children: Regional differences in Crete persist

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Abstract

Aim: To examine whether secular trends in adiposity and blood lipid profile of Greek children manifested equally among individuals from urban and rural provinces. *Methods*: Cretan boys (aged 12.1 ± 2.3 y) from urban and rural areas of Crete were recruited in 1982 ($n = 277$ and 251, respectively) and 2002 ($n = 440$ and 180, respectively). Height, weight, and body mass index (BMI), as well as plasma lipid concentrations were measured and compared across cohorts (1982 vs 2002) and regions (urban vs rural) by two-way analysis of covariance (adjusted for age) with interaction. *Results:* Temporal changes in height (positive), weight (positive), and BMI (positive) manifested equally in children from urban and rural provinces, as no interaction was detected. Similar results were obtained for triacylglycerol (positive), low-density lipoprotein cholesterol (LDL-C, positive) and high-density lipoprotein cholesterol (negative) concentrations. A significant interaction was observed only for total cholesterol (TC), which increased from 1982 among rural (by 6.2%, $p < 0.05$) but not among urban boys. In all other instances, regional differences in 1982 persisted in 2002. More specifically, children from urban provinces were taller, heavier, and had higher BMI values than those from rural areas, while they also had higher LDL-C concentrations, whether nowadays or 20 y ago. Regional differences in TC in 1982 were not apparent in 2002.

Conclusion: These findings suggest that changes in anthropometric characteristics and plasma lipids during the past 20 y have occurred largely in parallel among urban and rural Cretan children, and they emphasize the importance of developing a common national strategy for the prevention and treatment of childhood obesity in Greece.

Key Words: *BMI, children, lipoproteins, obesity, socio-economic*

Introduction

In recent decades, childhood obesity has evolved into a worldwide epidemic. This trend is alarming and calls for new preventative and treatment strategies [1], as excess body weight and/or fat early in life may have serious health complications. The consequences of pediatric obesity are multidimensional. In the short term, these may include orthopedic, neurological, pulmonary, gastroenterological, and endocrine health problems [2]. An adverse cardiovascular disease risk profile is commonly observed among overweight and obese children and adolescents; this usually tracks into adulthood, hence predicting increased adult cardiovascular morbidity and mortality [2]. Among the various cardiovascular risk factors associated with childhood obesity, dyslipidemia is probably the most common [3], and significant tracking of blood lipids from childhood to adulthood has been documented across several populations [4].

The two key responses to any epidemic are to discover the causes of the epidemic disease and to characterize the epidemic; the latter needs to occur in relation to prevalence, distribution across the populations, and secular trends. Studies examining secular trends provide an opportunity for prevention, by

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making an important contribution to the development of an effective public policy response. Although several investigators have studied temporal changes in anthropometric characteristics of children and adolescents in many parts of the world [5–15], comparably less is known regarding secular trends in blood lipids, and results have generally been isolated and inconsistent [16–19]. Further, only a few studies have simultaneously examined time changes in both adiposity and lipid profile [20–22].

Importantly, we still lack a clear understanding of how the factors associated with the socio-economic status of the pediatric population may have affected these trends. The more or less rapid urbanization that has occurred during the previous decades has had profound effects on the health and well-being of children [23]. Previous research has shown that the patterns of change in overweight and obesity vary considerably across countries and differ by age group, sex, rural or urban residence, and socio-economic status within countries [24]. Thus, generalization of the aforementioned time trends for populations with different socio-economic statuses, family background, etc. would not seem prudent. Taking all this information into consideration, the present study was designed to examine whether secular changes in adiposity and blood lipid profile of Greek children during 1982–2002 manifested equally among individuals from urban and rural provinces.

Subjects and methods

Study population

All child participants were registered in primary and secondary education public schools throughout Iraklio, which is the largest of the four counties of the island of Crete. The 1982 sample was selected from a larger cohort of children recruited from four geographical locations in Greece who took part in a cross-cultural study of cardiovascular risk factors between US and Greek adolescents in the early 1980s [25]. For reasons of comparison, the 2002 sample was selected from the exact same regions throughout the county of Iraklio and, in most cases, from the same schools of each region. A random, stratified selection approach was used in both survey years (1982 and 2002), taking into account the socio-economic distribution of the population (urban and rural) on the basis of the previous year's census (i.e. the censuses of 1981 and 2001). During this time period, the total population of Iraklio county increased by some 20% (from 243 500 in 1981 to 292 500 in 2001), with a redistribution in favor of urban residence (from approximately 54% in 1981 to 65% in 2001). Urban regions had more than 100 000 (in 1982) or 150 000 (in 2002) inhabitants (the town of Iraklio and nearby suburbs), while rural regions had less than 4000 (in 1982) or 3000 (in 2002) inhabitants each (small villages spread on the mountainous areas throughout the county). Blocks of the town of Iraklio and villages throughout the county were randomly selected, and all boys aged 9, 12 and 15 y living in them were included in the study. A member of the research team visited all children at their place of residence. Participation rates were 75.4% in 1982 and 81.6% in 2002. A complete set of data was collected from 1148 boys. An additional 11 subjects in 1982 (5 urban and 6 rural boys) and 9 subjects in 2002 (6 urban and 3 rural boys) had incomplete data sets and were therefore excluded from the analysis. All participants visited the Preventive Medicine and Nutrition Clinic of the University of Crete during the first semester of each year (January–June), where information was collected by trained personnel.

Ethics

Prior to enrollment, children's parents or guardians were fully informed about the objectives and methods of the study and signed a written consent. The children provided their verbal assent. Approval to conduct the survey was granted by the Ethical Committee of the University of Crete.

Anthropometric measurements

Body weight was measured by a medical spring scale in 1982 with an accuracy of 0.5 kg, and a digital scale in 2002 with an accuracy of 0.1 kg. Subjects were weighed without shoes, in their underwear or light clothing. Standing height was measured without shoes to the nearest 0.5 cm using a portable wall-mounted stadiometer, with the shoulders in a relaxed position and the arms hanging freely (stretch stature method). Body mass index (BMI, kg/m^2) was calculated as weight (kg) divided by height (m) squared, and was used for subjects' classification as normal weight, overweight, and obese, according to the previously proposed cut-off points for childhood overweight and obesity adopted by the International Obesity Task Force (IOTF) [26].

Blood lipid measurements

Forearm venous blood samples (10 ml) were obtained from each child in the morning before breakfast, following an overnight fast (>12 h). Plasma was separated by low-speed centrifugation using a bench centrifuge, and was stored at $-80°C$ until further analyses. The laboratory procedures followed in 2002 were identical to those in 1982. Total cholesterol (TC) was determined enzymatically [27], high-density lipoprotein cholesterol (HDL-C) was measured by the heparin-manganese precipitation method [28], and triacylglycerol (TG) was determined colorimetrically [29]. Reagents were obtained from Sigma Diagnostics (St. Louis, MO, USA), and assays were carried out in duplicate on a centrifugal autoanalyzer. Within-batch coefficients of variation for the determination of plasma lipid parameters were below 5% in both survey years. Low-density lipoprotein cholesterol (LDL-C) was calculated by the Friedewald et al. [30] equation. The TC/HDL-C and LDL-C/HDL-C ratios were also estimated.

Statistical analysis

Results are reported as means ± standard deviations (SD) or as proportions (%) and 95% confidence intervals (CI). All variables were tested for normality, and those that were not normally distributed were logarithmically transformed prior to the analysis. To examine cohort- and region-related differences, a two-way analysis of covariance (ANCOVA) with interaction, including cohort and region as main effects, was performed. Age was used as a covariate. The Bonferoni adjustment was used for *post hoc* comparisons of means. When significant interactions did emerge, meaning that differences between cohorts were not the same in both regions, or alternatively, that differences between regions were not the same in both cohorts, within-group comparisons were also made, using one-way ANCOVA followed by the Bonferoni adjustment. Distributions across the levels of a categorical variable (e.g. percentage normal weight, overweight, and obese) were compared across cohorts and regions by the non-parametric χ^2 test of independence. When statistically significant associations between cohort and/or region for a given response were revealed, the 95% CI of the point estimate was used to identify which categories differed significantly from each other. Statistical significance was set at $p<0.05$. All analyses were carried out using SPSS 10.0.5 for Windows (SPSS Inc., Chicago, IL, USA).

Results

Anthropometric characteristics

The mean age of the children was 12.1 ± 2.3 y, and was significantly different between cohorts and/or regions ($F=22.0$, $p<0.001$), with a significant two-factor interaction ($p<0.001$). Hence, age was used as a covariate in all subsequent analyses. A significant main effect of both cohort and region was revealed for height, weight, and BMI, with no interaction between the two (Table I). In particular, contemporary boys were taller than those in the 1980s (152.4 ± 7.5 vs 150.6 ± 6.9 cm, respectively; $p<0.001$). Similarly, they were heavier (49.8 ± 12.4 vs 45.5 ± 11.5 kg, respectively; $p<0.001$) and had higher BMI values (20.93 ± 4.23 vs 19.36 ± 3.91 kg/m^2, respectively; $p<0.001$). Furthermore, children from urban areas were taller compared to those living in rural areas (152.0 ± 8.0 vs 151.0 ± 6.2 cm, respectively; $p=0.014$). They were also heavier (48.7 ± 10.7 vs 46.6 ± 10.4 kg, respectively; $p=0.002$) and had higher mean BMI (20.46 ± 3.75 vs 19.83 ± 3.74 kg/m^2, respectively; $p=0.008$). Differences in the anthropometric characteristics between 1982 and 2002 hold true for both regions, while those between urban and rural areas hold true for both cohorts (Table I).

Prevalence of abnormal body weight

Children were classified as normal weight, overweight, and obese according to the age- and gender-specific pediatric percentiles corresponding to an adult BMI value of 25 kg/m^2 for overweight and 30 kg/m^2 for obesity [26]. Overall, there was a statistically significant association between cohort and/or region and the prevalence of normal and abnormal body weight ($\chi^2=61.6$, df = 6, $p<0.001$). In both urban and rural areas, the prevalence of obesity was approximately threefold higher nowadays than in the 1980s (Table II). Accordingly, the percentage of boys with normal body weight has declined significantly since 1982, by some 20% and 14% in urban and rural provinces, respectively. As a result, the prevalence of overweight was higher in 2002 among the urban but not the rural children (Table II). On the other hand, there were no significant differences between regions in 1982 ($\chi^2=2.8$, df = 2, $p=0.252$), contrary to what was observed in 2002 ($\chi^2=6.1$, df = 2, $p=0.047$). In the latter instance, however, a clear distinction between

Table I. Anthropometric characteristics of the study participants.

	1982		2002		Two-way ANCOVA p-values		
	Urban ($n=277$)	Rural ($n=251$)	Urban ($n=440$)	Rural ($n=180$)	Cohort	Region	C × R
Height (cm)	151.3 ± 6.7^a	149.9 ± 6.3	152.8 ± 6.3^{a,b}	152.1 ± 6.7^b	<0.001	0.014	0.379
Weight (kg)	46.3 ± 11.7^a	44.8 ± 11.1	51.2 ± 10.5^{a,b}	48.4 ± 10.7^b	<0.001	0.002	0.350
Body mass index (kg/m^2)	19.53 ± 3.83^a	19.19 ± 3.96	21.38 ± 3.78^{a,b}	20.47 ± 3.76^b	<0.001	0.008	0.232

Values are shown as means ± SD, and have been adjusted for age.
[a] $p<0.05$ vs rural region (within-cohort).
[b] $p<0.05$ vs 1982 (within-region).

Table II. Prevalence of overweight and obesity.

	1982		2002	
	Urban ($n=277$)	Rural ($n=251$)	Urban ($n=440$)	Rural ($n=180$)
Normal weight (%)	77.3 (72.3, 82.2)	81.7 (76.9, 86.5)	57.3 (52.7, 61.9)[a]	67.8 (61.0, 74.6)[a]
Overweight (%)	17.3 (12.9, 21.8)	15.5 (11.1, 20.0)	28.6 (24.4, 32.9)[a]	22.8 (16.7, 28.9)
Obese (%)	5.4 (2.7, 8.1)	2.8 (0.8, 4.8)	14.1 (10.8, 17.3)[a]	9.4 (5.2, 13.7)[a]
Overweight + obese (%)	22.7 (17.8, 27.7)	18.3 (13.5, 23.1)	42.7 (38.1, 47.3)[a]	32.2 (25.4, 39.0)[a]

Values are shown as point estimates (95% CI).
[a] $p<0.05$ vs 1982 (within-region).

urban and rural areas failed to manifest, as there was a slight overlap in the 95% CI of the point estimates (Table II).

When overweight and obese children were grouped together, a statistically significant association between this two-way classification (i.e. normal or abnormal; the latter including overweight and obese) and the cohort and/or region was observed ($\chi^2=51.2$, df$=3$, $p<0.001$). Using separate 2×2 cross-classifications allowed for estimating odds ratios for abnormal body weight in 2002 relative to 1982, and in rural regions relative to urban ones. Following a within-region (i.e. between cohorts) analysis, an odds ratio of 2.53 (CI$=1.79$, 3.57; $\chi^2=29.8$, df$=1$, $p<0.001$) for urban areas and 2.11 (CI$=1.34$, 3.32; $\chi^2=11.1$, df$=1$, $p=0.001$) for rural areas was obtained, meaning that the odds of being overweight or obese in 2002 were 2.53 times greater than in 1982 for children living in urban provinces, and 2.11 times greater for those living in rural provinces. On the other hand, a within-cohort (i.e. between regions) analysis revealed an odds ratio of 0.78 (CI$=0.50$, 1.21; $\chi^2=1.6$, df$=1$, $p=0.210$) for the 1982 cohort and 0.65 (CI$=0.45$, 0.93; $\chi^2=5.9$, df$=1$, $p=0.015$) for the 2002 cohort. That is, children from rural areas in 1982 had the same odds of being overweight or obese as those living in urban areas, while by contrast, in 2002, these odds were 0.65 times lower in rural versus urban boys.

Blood lipid profile

With respect to plasma lipids, a significant main effect of cohort was detected in all the parameters measured, while regional differences were noted for TC and LDL-C concentrations; the only significant interaction between cohort and region was observed for TC (Table III). Within-cohort analysis revealed that urban children in 1982 had significantly higher TC than their peers from rural regions ($p=0.005$), but this difference was not evident in 2002 ($p=0.937$). On the other hand, both nowadays and 20 y ago, LDL-C was significantly higher in boys from urban versus rural areas. No other regional differences could be identified, whether in 1982 or 2002 (Table III). On the other hand, contemporary children had higher LDL-C and TG and lower HDL-C concentrations, as well as higher TC/HDL-C and LDL-C/HDL-C ratios compared to those in the 1980s; this held true for both urban and rural areas (Table III). The only deviation from this general scheme was observed for TC. Its concentration was significantly higher in 2002 versus 1982 among rural provinces, but this was not the case for urban ones (Table III). To examine whether differences in BMI between cohorts and regions were responsible for the observed differences in blood lipids, the analysis was repeated after controlling for BMI. The results for the main effects of cohort and region,

Table III. Blood lipid profile of the study participants.

	1982		2002		Two-way ANCOVA p-values		
	Urban ($n=277$)	Rural ($n=251$)	Urban ($n=440$)	Rural ($n=180$)	Cohort	Region	C × R
TC (mmol/l)	4.29 ± 0.83[a]	4.06 ± 0.79	4.35 ± 0.84	4.35 ± 0.80[b]	0.001	0.019	0.029
HDL-C (mmol/l)	1.77 ± 0.50	1.75 ± 0.48	1.32 ± 0.42[b]	1.33 ± 0.40[b]	<0.001	0.768	0.583
LDL-C (mmol/l)	2.21 ± 0.83[a]	2.03 ± 0.79	2.69 ± 0.84[a,b]	2.66 ± 0.67[b]	<0.001	0.025	0.145
TG (mmol/l)	0.64 ± 0.33	0.63 ± 0.32	0.73 ± 0.42[b]	0.79 ± 0.27[b]	<0.001	0.320	0.169
TC/HDL-C	2.58 ± 1.17	2.48 ± 1.11	3.47 ± 1.05[b]	3.46 ± 0.94[b]	<0.001	0.407	0.509
LDL-C/HDL-C	1.40 ± 1.00	1.30 ± 1.11	2.19 ± 0.84[b]	2.16 ± 0.94[b]	<0.001	0.230	0.594

Values are shown as means ± SD, and have been adjusted for age.
[a] $p<0.05$ vs rural region (within-cohort).
[b] $p<0.05$ vs 1982 (within-region).

however, as well as for their interaction, were not substantially affected (data not shown). There was only a non-significant trend ($p = 0.060$) for age- and BMI-adjusted TG concentration to be higher among children from rural versus urban areas.

Overall secular trends

To enable a visual representation of the differences in anthropometric characteristics and blood lipid profile between 2002 and 1982, mean absolute differences for urban and rural regions have been expressed as percentage of the respective values in 1982—using the formula: difference from 1982 (%) $= 100 \times$ (2002 value $-$ 1982 value)/1982 value—and are graphically illustrated in Figure 1. Clearly, 20-y changes in height, weight, BMI, and plasma lipids were largely similar for urban and rural areas. The only exception was TC, which manifested an increase since 1982 among rural children only.

Discussion

The present study was carried out to examine secular trends in adiposity and blood lipid profile among school-aged boys from urban and rural provinces of Crete, Greece, during 1982–2002. Our results show significant increases in the mean height, weight, and BMI (Table I) and, consequently, in the prevalence of pediatric overweight and obesity (Table II). These findings are in accord with data from other countries [5–14]. Previous research suggests that not only the prevalence of overweight and obesity in children has been rising during the past decades, but that it has increased more rapidly from the 1980s onwards [8–10,14]. For instance, the prevalence of overweight and obesity in US children and adolescents aged 5–24 y has approximately doubled from 1973 to 1994, and yearly increases during the latter part of the study (1983–1994) were almost 50% greater than those during 1973–1982 [10]. Similar results have been obtained for British boys aged 9–11 y, as there was little overall change in overweight and obesity prevalence rates during 1974–1984, but there was an apparent doubling from 1984 to 1994 [9]. Likewise, secular trends in Australian children aged 7–15 y were negligible during 1969–1985, but the prevalence of overweight and obesity increased by almost 1.7 and more than 3 times, respectively, during 1985–1997 [8]. Although these worrisome trends have been documented across all ages and both genders, they appear to be somewhat more pronounced among males 10–15 y old [11–13].

Further, secular changes in anthropometric characteristics manifested equally in the Cretan pediatric population from urban and rural provinces; hence, any regional differences in 1982 persisted in 2002. For instance, children from urban areas were taller, heavier, and had higher BMI values than their rural contemporaries either nowadays or 20 y ago (Table I). Time trends in the prevalence of overweight and

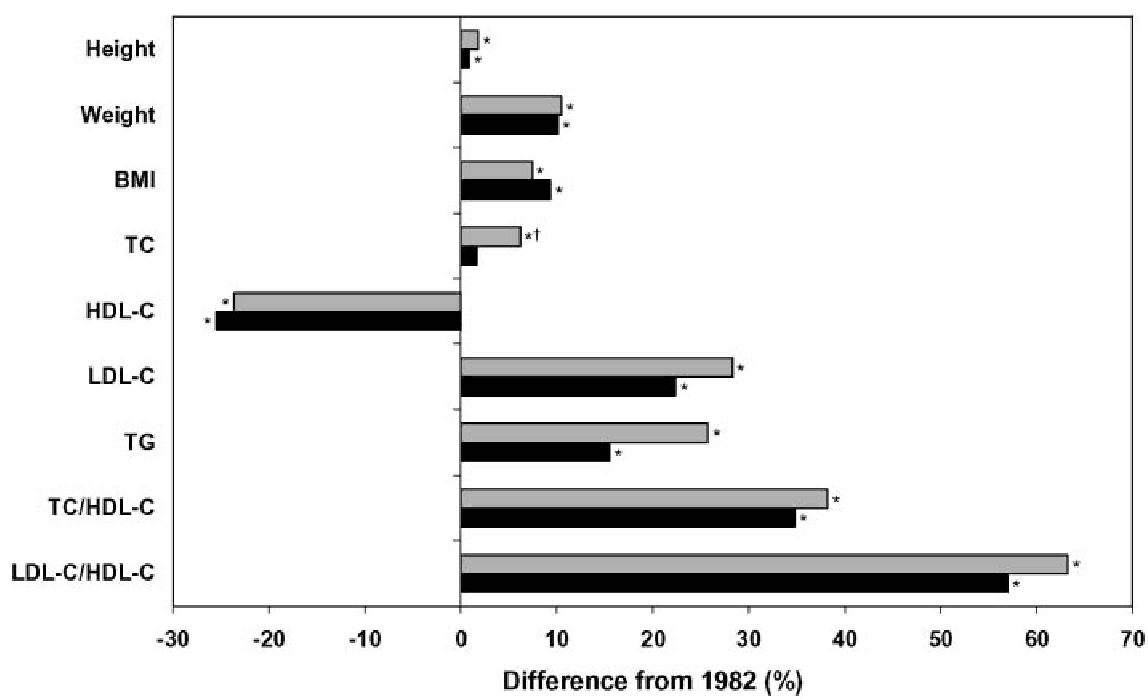

Figure 1. Twenty-year changes in anthropometric characteristics and plasma lipids of school-aged boys from urban (black bars) and rural (gray bars) provinces of Crete. Values are expressed as percentage difference between 2002 and 1982, taking the latter cohort as the baseline. *$p < 0.05$ vs zero (i.e. for 2002 vs 1982); † $p < 0.05$ vs change in urban regions.

obesity were also largely similar, though not identical, between urban and rural areas (Table II). Previous studies comparing secular trends in adiposity among children and adolescents living in urban or rural settings are scarce. Rasmussen et al. [7] analyzed trends in overweight and obesity in Swedish 17-y-old males between 1971 and 1995. They, too, reported significant upward trends that were similar for those living in large cities and those living in rural or sparsely populated areas [7]. Likewise, Moreno et al. [31] documented equal increases in the prevalence of overweight and obesity between 1985 and 1995 among Spanish adolescents aged 13–14 y old, living in large or small municipalities (defined as those with more or less than 10 000 inhabitants, respectively). Further, Strauss et al. [13] reported comparable yearly rates of increase in overweight and obesity among 4- to 12-y-old US children living in urban or rural areas during 1986–1998. Apparently, therefore, at least in the so-called westernized societies, the gradual urbanization during the previous decades has equally affected individuals from both urban and rural settings. Still, annual changes in the prevalence of overweight and obesity in children from urban and rural areas during the past 2–3 decades have been reported to vary considerably across countries, with no regional differences in the US and Russia, but a threefold greater increase among urban versus rural children in Brazil and a 10-fold one in China [24].

With respect to secular trends in blood lipids, results from the limited number of available studies are inconsistent. Using data from the Third National Health Examination Survey, and the First and the Third National Health and Nutrition Examination Surveys, it was reported that TC in white US boys aged 12–17 y remained relatively stable over 1966–1974 and, in fact, declined during 1974–1994 [17]. Data from the Bogalusa Heart Study, however, revealed no such decrease over 1973–1988 in 10-y-old children [19], while, on the contrary, findings from the Princeton School Study showed a significant increase in mean TC concentration and, accordingly, in the prevalence of hypercholesterolemia during 1975–1990 [18]. An increase in TG and a decrease in HDL-C, accompanied by small increases in TC and LDL-C, have also been reported for US children during 1984–1992, but not during 1973–1981 [21]. Finally, the Cardiovascular Risk in Young Finns Study documented a mean decrease in TC (−8.5%) and LDL-C (−7.5%), but also in HDL-C (−19%), and a mean increase in TG (+15%), among Finnish adolescents aged 15 and 18 y between 1980 and 1992 [20]. In the present study, we have documented significant adverse changes in all plasma lipid concentrations, whether in urban or rural provinces (Table III). Further, other than LDL-C, regional differences in blood lipids were scarce, and 20-y trends in urban and rural areas paralleled each other. Although it appeared that adverse changes were somewhat more pronounced among rural boys, only in the case of TC did this difference reach statistical significance. TC concentration has increased by approximately 6.2% during the past 20 y among rural, but not among urban youngsters, in whom a non-significant 1.6% change was detected (Figure 1).

It is unclear why there has been so much variability across and within countries in reported secular trends in blood lipids among children and adolescents. These variations could relate to differences in key environmental factors, such as different temporal changes in dietary and physical activity patterns, or perhaps to genetic factors that govern plasma lipid response to environmental stimuli. In this respect, it is interesting to refer to a recent comparative study between Japanese, Spanish, and US children 1–18 y old [22]. In the Japanese, mean TC has increased by 6.5% from 1960 to 1980, and by an additional 3.5% from 1980 to 1990. Likewise, mean TC has increased by more than 6% in Spanish children during 1982–1985. On the other hand, mean TC in US children has not changed significantly over 1974–1992. The authors have also taken into account secular changes in adiposity, physical activity, and dietary fat intake, and concluded that differences in these parameters were not likely to explain differences in TC concentrations across the three populations [22]. Therefore, the hypothesis was advanced that increasing total and saturated fat intake in populations not previously exposed to such intakes, such as the Japanese and the Spanish, could possibly lead to greater and more adverse changes in blood lipid profiles than in populations long adapted to Western diets by genetic selection or other mechanisms, such as the US [22]. This could possibly explain some of the variability in reported secular trends in blood lipids to date.

Regardless of the underlying environmental, lifestyle, and/or behavioral mechanisms, however, the significant rise in the prevalence of overweight and obesity and the considerable adverse changes in blood lipid profile since 1982 that have been documented in the present study among both urban and rural Cretan children are alarming, as they predict unfavorable health outcomes in the foreseeable future. Currently, Greek children are ranked among the fattest in the European Union, with adiposity rates being similar to those among US children [32]. Our findings therefore emphasize the importance of developing a common national strategy for the prevention and treatment of obesity in Greek children and adolescents.

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