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Research paper

Trends in metabolic syndrome risk factors among adolescents in rural Crete between 1989 and 2011

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ABSTRACT

OBJECTIVE: To investigate all the important factors contributing to the development of metabolic syndrome (MetS) as well as to explore the changes of these factors, over time, by comparing adolescent populations of rural areas of Heraklion, Crete, for the years 2011 and 1989. DESIGN: This study was carried out within two rural areas of the Heraklion region in Crete, Greece. The 1989 study was conducted in the village of Agia Varvara and the respective 2011 study within the municipality of Minoa Pediados. The study population consisted of 150 high school students (97 girls and 69 boys) in 1989 and 66 (30 girls and 36 boys) elementary (6th grade) and high school students in 2011, aged from 12 to 14 years old. Anthropometric, blood pressure and biochemical information was obtained. RESULTS: Of the MetS risk factors studied, only obesity incidence was found higher in 2011 compared to 1989 (obese adolescents 1.3% in 1989 versus 21.2% in 2011, p<0.001). On the other hand, hypertension levels were higher in 1989 compared to 2011 (46.7% versus 6.3%, respectively, p<0.001). In addition, glucose and LDL-C levels were lower in 2011. CONCLUSIONS: The present study supports the fact that there are significant changes in metabolic risk factors through time in adolescent populations of Crete, mainly due to the rise in obesity levels as well as to the decrease in hypertension, total cholesterol and LDL- cholesterol, as observed from the comparison of the years 1989 and 2011.

Key words: Adolescents, Metabolic syndrome risk factors, Obesity, Overweight, Rural Crete

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INTRODUCTION

The Metabolic Syndrome (MetS) is a major public health issue worldwide.[1] MetS was first known as the X syndrome in 1988 and was believed to form a link between hypertension, dyslipidemia, insulin resistance, Type 2 Diabetes (T2D) and other metabolic abnormalities associated with an increased risk for cardiovascular disease (CVD) in adulthood.[2,3]

After several transformations to the definition of the MetS among adults, in 2007 the International Diabetes Federation provided the first definition for children and adolescents. Accordingly, MetS is characterized by the coexistence of several metabolic disorders such as obesity, increased blood glucose, hypertension, low levels of HLD cholesterol and elevated triglycerides.[4] Specifically, risk factors for adolescents MetS evaluation are: abdominal obesity estimated by waist circumference, triglycerides (TRIG) levels, HDL-C levels, systolic blood pressure (SBP) or diastolic blood pressure (DBP) and blood glucose levels (GLU). Cut-offs were used as defined by the International Diabetes Federation (International Diabetes Federation, 2007). MetS syndrome patients are considered to be those who have three or more of the above factors.[4]

The continuous increase in MetS prevalence among adults is closely associated with MetS risk factors, that begin to develop in childhood. Pediatric researchers have found that the indicators of MetS are moderately stable from childhood to adolescence and from adolescence to young adulthood.[5] Adolescence is a critical transitional period that includes the biological changes of puberty, characterized by changes in body composition (location and quantity of body fat), physical fitness and decreased insulin sensitivity. This period of growth and maturation is also marked by behavioural changes in diet, physical activity, sedentary behaviour and psychological health with possible influences on health.[6] Subjects with MetS in adolescence are two or three times more likely to have myocardial infarction or stroke and almost five times to develop T2D during adulthood.[7] Several analyses of the NHANES study, which was conducted at a national level in the USA, showed that the prevalence of MetS in adolescents is lower compared to adults.[8,9] Moreover, 9.2% of the adolescent population of the USA from 1988 to 1994 was qualified as having MetS, 30% of whom were obese and overweight.[9] Of note, in a nationwide study in Korea, the prevalence increased from 6.8% in 1998 to 9.2% in 2001.[10] A previous Greek study that determined the prevalence of MetS in adolescents found 0.7% of them with MetS.[11]

Obesity is believed to be the key factor for MetS development.[12] Today, the obesity epidemic is a major problem worldwide with the number of obese children increasing alarmingly. Regions such as North America and Europe have the highest prevalence of obese children, ranging between 20% and 30%.[13] Obesity is associated with increased risk of cardiovascular disease and is known to be a quite important factor for T2D development.[14] Furthermore, obesity during adolescence portends a significant risk of premature death from cardiovascular diseases later in adulthood.[15]

It is commonly accepted that over the past few decades, Greece has experienced a shift from the traditional Mediterranean to a western-type diet, along with a transition from an active to a sedentary lifestyle.[16] Such lifestyle changes have played a major role in the rapid rise of overweight among many school children in Greece as well as in other countries, including the US, Ireland and Portugal whose children are among the most overweight internationally.[17] A study conducted by Karlen et al[18] in 2008, compared the dietary behavior of a rural children population in Crete and Sweden. This report stated that Cretan children, in contrast to the results of the Seven Countries study in which the island of Crete was documented as having the lowest prevalence of cancers and coronary heart disease globally, due to the Mediterranean Diet,[19] have abandoned some aspects of the traditional Mediterranean Diet, even in rural areas.[18]

Moreover, the prevalence of childhood obesity (1982 versus 2002) in rural areas of Crete was 9.4% according to the 2005 study of Manios et al.[20] A rural population study of 17-year-old adolescents in Greece also found that 51.2% of the boys and 21.3% of the girls were overweight. Furthermore, 7.1% of the study sample was diagnosed with central obesity.[21]

Such studies are important from a public health perspective, since identification of MetS factors that predispose to morbidity could help public health professionals to develop more effective preventive measures.

Therefore, the present study aimed to investigate all the important factors that contribute to the development of MetS as well as to explore the changes of these factors, over time, by comparing adolescent populations from rural areas of Heraklion, Crete, for the years 2011 and 1989.

SUBJECTS AND METHODOLOGY

Subjects

This study was carried out in 2011 within the municipality of Minoa Pediados, a rural area near Heraklion, Crete. The study population comprised elementary (6^{th} grade) and high school students. The total number of participants was 66 (30 girls and 36 boys) out of 98 requested to participate (Response Rate: 67.3%). Respectively, for the year 1989, the study was carried out at the high school of Agia Varvara, a similar rural area near Heraklion with students of the same age group. Additionally, from Agia Varvara, 150 adolescents (97 girls and 69 boys) out of 180 agreed to participate (Response Rate: 83.3%). In both cases, parents were asked to give written permission for their children's participation. The ethical committee at the University of Crete approved the protocol of the study.

Anthropometric measurements

Students were weighed to the nearest 0.1 kg in light clothing and without shoes by using a digital scale Seca Alpha for the 2011 study (Seca for the 1989 study). Height was measured to the nearest 0.5 cm using a commercial stadiometer with the participants barefoot, their shoulders in a relaxed position, their arms hanging freely and their heads in the Frankfort horizontal plane. Body mass index (BMI) was calculated by dividing weight (kg) by height squared (m^2). The International Obesity Task Force thresholds were used to categorize children into underweight, normal-weight, overweight and obese.[22]

The total number of 2011 participants who underwent anthropometric measurements was 66, while in 1989 it was 150.

Blood pressure measurements

SBP and DBP blood pressure measurements were performed with the use of electronic sphygmomanometer (Omron) in 2011 and mercury sphygmomanometer in 1989, while subjects were seated with their back supported and resting for at least 5 minutes before each measurement. The measurement was taken three times, with a 2-3 min interval between each reading. The average of the three measurements was recorded.

The total number of 2011 participants who underwent blood pressure measurements was 64 (97%), while in 1989 it was 150 (100%).

SBP and DBP measurements were adjusted only for age and gender since all of the participants were around the 50^{th} percentile of height. BP were grouped into the normal range (50^{th} percentile), pre-hypertensive (90^{th} to $<95^{th}$ percentile) and hypertensive ($>95^{th}$ percentile).[23] This process was carried out for both SBP and DBP. Depending on the percentile of each BP, we had the general characterization of BP which means that if both SBP and DBP were $<90^{th}$ percentile the BP was normal, if one of each was from 90^{th} to $<95^{th}$ percentile the subject was pre-hypertensive and finally if at least one was $>95^{th}$ percentile the subject was hypertensive.[23]

Biochemical analyses

10 ml of blood samples were taken at school time, during the morning, after a 12 hour overnight fast. The blood samples of 2011 were transferred to the PAGNI hospital of Heraklion for the analysis, while the 1989 samples were analyzed at the Nutrition Research Laboratory of the University of Crete in tanks containing ice packs so as to maintain a temperature of 3-4 °C. Blood was centrifuged and 1.5 ml aliquots were pipetted into plastic Eppendorf tubes. One aliquot was used for blood analysis of triglycerides (TRIG), total cholesterol (TC) and high density lipoprotein cholesterol (HDL-C) measurements in the same year of the collection, while the other was stored at -80 °C. Low density lipoprotein cholesterol (LDL-C) was calculated as:[24]

$$\text{LDL cholesterol} = \text{TC-HDL cholesterol} - (\text{TG}/5)$$

Finally, GLU levels were measured with the enzymatic method GOD-PAP.[25]

The total number of 2011 participants with blood tests was 57 (86.4%), while for 1989 they were 55 (36.7%). Hyperglycemia was defined as blood glucose levels above 100 mg/dl[4]. Total cholesterol levels more than 170 mg/dl and/or TRIG levels more than 75 mg/dl[26] and/or HDL-C levels less than 40 mg/dl and/or LDL-C levels above 100 mg/dl are associated with increased risk for CVD. Based on the above recommendations we categorized biochemical indices as follows: TC (Normal <170 mg/dl, High >170 mg/dl), HDL-C (Normal >40 mg/dl, High <40 mg/dl), LDL-C (Normal <100 mg/dl, High >100 mg/dl), TRIG (Normal <75mg/dl, High >75 mg/dl), (American Academy of Paediatrics 1992) and GLU (Normal <100 mg/dl, High >100 mg/dl).[4]

Statistic analysis

Following application of Levene's test (of homogeneity of variance), Analysis of Covariance was used to assess differences in average concentrations of HDL and LDL-C, TC, TRIG, GLU, SBP, DBP and BMI, adjusted for age and gender. In addition, the Chi squared test was used to detect the differences in the frequencies of several MetS parameters between 2011 and 1989 (BMI, blood pressure, SBP, DBP, HDL and LDL-C, TC, TRIG and GLU categories as described above). The level of significance for the analysis was set at $\alpha=5\%$, while the data analysis was performed with the use of the statistic package PASW SPSS (Version 18).

RESULTS

The study sample in 1989 consisted of 150 participants, 85 girls (56.7%) and 65 boys (43.3%), while the study sample in 2011 consisted of 30 girls (45.5%) and 36 boys (54.5%), p=0.185. The mean age in the 1989 subjects was 13.1 years (standard deviation=0.62), while in 2011 mean age was 13.6 years (standard deviation = 0.9), p=0.061.

As depicted in Table 1, the TRIG & HDL-C levels were not found to differ between the two time periods (Mean difference=-7.9, 95% CI for difference= -28.8 to -12.9, p=0.452 & Mean difference= 3.5, 95% CI for difference =-1.2 to 8.2, p= 0.114, respectively). However, in 2011 the GLU levels were lower by 6.1mg/dl, p=0.001. Similarly, SBP (-8.2 mm Hg, 95% CI for difference: -11.2 mm Hg to -5.2 mm Hg, p<0.001), DBP (-17.1 mm Hg, 95% CI for difference: -19.4 mm Hg to -14.7 mm Hg, p<0.001), TC (-13.5 mg/dl, 95% CI for difference: -24.7 mg/dl to -2.4 mg/dl, p=0.018) and LDL-C (-16.4 mg/dl, 95% CI for difference: -27 mg/dl to -5.8 mg/dl, p=0.03) levels were significantly lower in 2011. By contrast, BMI differed between the two time periods, as the mean change from 1989 to 2011 was 2.5 kg/m^2 (95% CI for difference: 1.5 kg/m^2 to 3.5 kg/m^2, p<0.001).

The comparison of BMI and blood pressure levels of 1989 and 2011 is displayed in Table 2. The comparison is presented both in total numbers of adolescent participants and by gender. As is shown, adolescent BMI levels during 2011 were higher compared to 1989. Specifically, 77.3% of the 1989 study population had a normal weight versus 53% of the population in 2011. Similarly, in 1989 21.3% of the population was overweight versus 25.8% in 2011. Finally, the percentage of obese adolescents in 2011

Table 1. Mean changes for anthropometric measurements and biochemical markers among 12 to 14 year olds of rural areas of Heraklion, Crete (2011 and 1989)

12-14 years old	2011 N=66 Mean (SE)	1989 N=150 Mean (SE)	Mean Difference	95% CI for difference	p-value
Mean systolic blood pressure, mm Hg*	109.0 (1.3)	117.2 (0.8)	-8.2	-11.2 to -5.2	<0.001
Mean diastolic blood pressure, mm Hg*	61.5 (1.0)	78.6 (0.6)	-17.1	-19.4 to -14.7	<0.001
Body Mass Index, kg/m^2	22.9 (0.4)	20.4 (0.3)	2.5	1.5 to 3.5	<0.001
Blood Glucose, mg/dl‡	84.8 (1.2)	90.9 (1.2)	-6.1	-9.5 to -2.6	0.001
Triglycerides, mg/dl‡	73.4 (7.2)	81.3 (7.3)	-7.9	-28.8 to -12.9	0.452
Total Cholesterol, mg/dl‡	162.1 (3.8)	175.6 (3.9)	-13.5	-24.7 to -2.4	0.018
HDL-C, mg/dl‡	52.3 (1.6)	48.8 (1.6)	3.5	-1.2 to 8.2	0.144
LDL-C, mg/dl‡	94.9 (3.6)	111.3 (3.7)	-16.4	-27.0 to -5.8	0.001

* Missing values: 2011= 2 (3.0%). ‡ Missing values: 1989=95(63.3%), 2011= 9 (13.6%).
Adjusted for age and gender. Analysis of covariance.

Table 2. Obesity (BMI) and blood pressure levels comparison between 2011 and 1989, among 12 to 14 years old adolescents, of rural areas of Heraklion Crete

	All participants			Girls			Boys		
	2011	**1989**		**2011**	**1989**		**2011**	**1989**	
12-14 years old	**N (%)**	**N (%)**	**p- value**	**N (%)**	**N (%)**	**p- value**	**N (%)**	**N (%)**	**p- value**
BMI									
Normal	35 (53.0)	116 (77.3)		18 (60)	68 (80)		17 (47.2)	48 (73.8)	
Overweight	17 (25.8)	32 (21.3)	<0.001	5 (16.7)	17 (20)	<0.001	12 (33.3)	15 (23.1)	<0.001
Obese	14 (21.2)	2 (1.3)		7 (23.3)	0 (0)		7 (19.4)	2 (3.1)	
Blood pressure									
Normal	54 (84.4)	35 (23.3)		27 (93.1)	21 (24.7)		27 (77.1)	14 (21.5)	
Pre-hypertension	6 (9.4)	45 (30)	<0.001	1 (3.4)	25 (29.4)	<0.001	5 (14.3)	20 (30.8)	<0.001
Hypertension	4 (6.2)	70 (46.7)		1 (3.4)	39 (45.9)		3 (8.6)	31 (47.7)	
Systolic Blood Pressure									
$<90^{th}$ percentile	54 (84.4)	92 (61.3)	0.004	27 (93.1)	52 (61.2)	0.006	27 (77.1)	40 (61.5)	0.256
90^{th} - $< 95^{th}$ percentile	6 (9.4)	30 (20)		1 (3.4)	17 (20)		5 (14.3)	13 (20)	
$\geq 95^{th}$ percentile	4 (6.2)	28 (18.7)		1 (3.4)	16 (18.8)		3 (8.6)	12 (18.5)	
Diastolic Blood Pressure									
$<90^{th}$ percentile	61 (95.3)	50 (33.3)		28 (96.6)	30 (35.3)		33 (94.3)	20 (30.8)	<0.001
90^{th} - $< 95^{th}$ percentile	3 (4.7)	43 (28.7)	<0.001	1(3.4)	22 (25.9)	<0.001	2 (5.7)	21 (32.3)	
$\geq 95^{th}$ percentile	0 (0)	57 (38)		0 (0)	33 (38.8)		0 (0)	24 (36.9)	

2011: Total = 66 (100%), Girls = 30 (45.5%), Boys = 36 (54.5%), 1989: Total = 150 (100%), Girls = 85 (56.7%), Boys = 65 (43.3%). Chi squared analysis.

was a spectacular 21.2% compared to only 1.3% in 1989, $p<0.001$. It should be noted here that there was no gender difference in the distribution of BMI levels. Specifically, 80% of the 1989 girls had normal weight and no one was found to be obese. On the other hand, in 2011, 60% of the girls had normal weight, 16.7% were overweight and 23.3% were obese ($p<0.001$).

It is of interest though that the comparison of blood pressure distribution was lower in the year 2011. Indeed, only 23.3% of the population in 1989 had normal BP compared to 84.4% in 2011. Furthermore, 46.7% in 1989 were hypertensives compared to only 6.2% in 2011 ($p<0.001$). Regarding SBP and DBP levels, the 2011 participants had lower rates of hypertension ($>95^{th}$ percentile). SBP measurements showed that 18.7% of the 1989 participants versus 6.2% in 2011 were found to be over the 95^{th} percentile ($p=0.004$), while 38% in 1989 were found to have DBP over the 95^{th} percentile ($p<0.001$).

In 1989, the percentage of hypertension in girls was higher compared to that in 2011. Indeed, only 3.4% of the 2011 girls were hypertensive compared to 45.9% in 1989 ($p<0.001$). Similar results were obtained in boys. More specifically, 3.1% of the 1989 participants versus 19.4% in 2011 were obese ($p<0.001$), while 47.7% of the 1989 boys had hypertension compared to only 8.6% in 2011, ($p<0.001$).

The comparison of serum lipids and glucose level is presented in Table 3. The data are presented both in total numbers of adolescent participants as grouped by gender. Analysis of the results showed that LDL-C and TC levels were higher in the 1989 subjects. Specifically, 29.1% of the 1989 adolescents versus 57.9% of 2011 had normal levels of LDL-C ($p=0.002$), while 63.6% of the 1989 participants had high levels of TC in comparison with 36.8% in 2011 ($p=0.008$). Gender analysis showed that girls did not have statistically significant differences in measurements of serum lipids and glucose level, while boys in 1989 had higher rates of LDL-C and TC than in 2011, namely 71.4% and 61.9% versus 34.4% and 31.2%, ($p=0.012$ & 0.047, respectively).

Table 3. Serum lipids and glucose levels comparison, between 2011 and 1989, among 12 to 14 years old adolescents, of rural areas of Heraklion Crete

12-14 years old	All cases			Girls			Boys		
	2011 N (%)	1989 N (%)	p- value	2011 N (%)	1989 N (%)	p- value	2011 N (%)	1989 N (%)	p- value
HDL-C									
<40 mg/dl	9 (15.8)	10 (18.5)	0.803	1 (4)	4 (12.1)*	0.378	8 (25)	6 (28.6)	1.00
>40 mg/dl	48 (84.2)	44 (81.5)		24 (96)	29 (87.9)		24 (75)	15 (71.4)	
LDL-C									
<100 mg/dl	33 (57.9)	16 (29.1)	0.002	12 (48)	10 (29.4)	0.179	21 (65.6)	6 (28.6)	0.012
>100 mg/dl	24 (42.1)	39 (70.9)		13 (52)	24 (70.6)		11 (34.4)	15 (71.4)	
Total Cholesterol									
<170 mg/dl	36 (63.2)	20 (36.4)	0.008	14 (56)	12 (35.3)	0.184	22 (68.8)	8 (38.1)	0.047
>170 mg/dl	21 (36.8)	35 (63.6)		11 (44)	22 (64.7)		10 (31.2)	13 (61.9)	
Blood Glucose									
<100 mg/dl	54 (94.7)	51 (92.7)	0.714	24 (96)	32 (94.1)	1.00	30 (93.8)	19 (90.5)	1.00
>100 mg/dl	3 (5.3)	4 (7.3)		1 (4)	2 (5.9)		2 (6.2)	2 (9.5)	
Triglycerides									
<75 mg/dl	33 (57.9)	34 (61.8)	0.703	11 (44)	18 (52.9)	0.339	22 (68.8)	16 (76.2)	0.395
>75 mg/dl	24 (42.1)	21 (38.2)		14 (56)	16 (47.1)		10 (31.2)	5 (23.8)	

2011: Total = 57 (100%), Girls = 25 (43.8%), Boys = 32 (56.2%). 1989: Total = 55 (100%), Girls = 34 (61.8%), Boys = 21 (38.2%)
*Missing value in 1989 girls = 1 (2.9%). Chi squared analysis.

DISCUSSION

The findings of the present study indicated several changes in MetS risk factors over time in a rural adolescent population of Crete, Greece. More specifically, alarming trends in overweight and obesity were observed from 1989 to 2011. On the other hand, blood pressure levels were found to be lower in 2011. Moreover, more participants in 1989 were above the cut-off points for normal LDL-C and TC levels in comparison to 2011.

The current existence of an obesity epidemic in childhood and adolescence is beyond any doubt.[13] Indeed, the estimated prevalence of obesity during 1960's in the USA was 4.2% for the ages 6-11 and 4.6% for the ages 12-19[27] compared to the period 2007-2008 when its prevalence rose to 19.6% and 18.1%, respectively.[28] Likewise, a study conducted in Japan with participants aged 6-14 years old showed that obesity levels doubled between 1974 to 1993.[29] Similarly, in the United Kingdom, Lobstein et al[30] found that obesity levels in children 7-11 years old rose from 8% to 20% in the period 1984-1998, while in France an increase of 12% was observed for the ages 5-12 years old from 1980 to 1991.[31] Finally, a study conducted in Greece found that obesity levels were 7% higher among adolescents today compared with the results of a 1942 study (6-12 years old).[32] Several Greek studies mainly in rural adolescent populations have also reported the alarming prevalence of obesity.[20,21,33] Tambalis et al[33] found that obesity in rural areas increased significantly from 7% in 1997 to 13% in 2008 in girls and from 8.2% to 14.1% in boys. Furthermore, the annual rate of obesity increase was 40%-50% higher in children from rural areas despite the higher fitness level.[33] In addition, a cross-sectional comparative study conducted by Smpokos et al[34] in 1st grade children in Crete, Greece, during 1992/93 and 2006/07 found that in 2006/07 boys had a higher percentage of overweight/obesity compared to those in 1992/93 (33.7% vs. 19.4% $p < 0.001$), while the percentage of overweight/obese girls in 2006/07 had also increased significantly over 1992/93 (34.6% vs. 24.5% $p=0.024$). It is thus clear that over the years an increase in obesity levels even in rural populations has been observed, as also indicated by the present study.

Obesity during childhood and adolescence is one of the most important risk factors for morbidity and mortality during adulthood.[35] In childhood, obesity can cause several metabolic or cardiovascular disorders including hyperinsulinemia.[36] Obesity increases the burden of non-communicable diseases by contributing to the risk for diabetes, ischemic heart disease, stroke, cancer and chronic disabling conditions such as osteoarthritis.[37] In addition, obesity may be responsible for asthma, obstructive sleep apnea syndrome and hypertension.[35]

The increased prevalence of childhood obesity in rural areas of Crete is particularly distressing because obese children tend to remain obese as adults and they often develop obesity-related diseases such as T2D, fatty liver disease and early stage cardiovascular diseases which are usually diagnosed in adulthood.[38] Factors that may have contributed to the increased levels of obesity include mother's smoking during pregnancy, lower rates of breastfeeding, hours of daily TV watching, the frequency of daily meals, the educational level of parents and mother's BMI.[39,40]

Consistent with the present study, Smpokos et al[34] found that while obesity levels in rural and urban areas of Crete increased over time, blood pressure levels were reduced. Moreover, the Bogalusa Heart Study (Louisiana) which examined 24,092 children and adolescents (5-17 years old) showed that the increase of obesity does not necessarily mean parallel increase of blood pressure. Specifically, they found that from 1974 to 1993 obesity increased from 6% to 17% but neither mean nor high blood pressure levels increased.[41] Khang et al,[42] using data from four waves (1998-2008) of KNHANES in boys and girls from 10 to 19 years old, demonstrated that prehypertension/hypertension prevalence decreased by 52% to 86%.

The Cuenca Study on 9-10-year-old Spanish children revealed that the incidence of overweight or obesity increased among boys, while SBP, DBP and HLD-C decreased in both genders over a 12-year period, though TRIG levels did not show substantial changes.[43] Okosun et al[44] examined data of U.S. National Health and Nutrition Examination Surveys concerning adolescents between 12-17 years old. Results showed an increase in waist circumference, a strong predictor for obesity, and decrease in LDL-C, TRIG and mean BP in a 10-year period between 1999-2000 and 2007-2008.

The findings of the present study are surprising because several studies have confirmed simultaneous increase of obesity and other cardiometabolic risk factors for adolescents younger than 16 years old.[45,46] It seems that BMI accounts for only a small degree of the variance in MetS risk factors during adolescence.[47] Other factors such as dietary habits, reduced salt intake from food, breastfeeding and physical activity could account for the observed reductions in blood pressure levels. Several studies have shown that reduced salt intake also reduces hypertension levels.[48] Chiolero et al[49] also found a correlation between breastfeeding and low blood pressure, a result that could possibly be explained by the fact that breast milk is low in salts and polyunsaturated fatty acids. Moreover, numerous factors such as physical activity, reduced intake of saturated fatty acids and cholesterol from the daily diet may be responsible for the reduced concentrations of TC and LDL-C over the period 1989-2011.[50] However, the above factors were not examined in the present study.

Elevated LDL-C levels are one of the most important factors associated with cardiovascular diseases, morbidity and mortality.[51] Furthermore, reduced levels of HDL-C are also connected with the increase of cardiovascular diseases prevalence.[52] Elevated levels of TRIG also contribute to the development of cardiovascular diseases.[51] Finally, hypertension increases morbidity and mortality due to implications which can lead to stroke, myocardial infarction or renal failure.[53]

Strengths and limitations of the study

The design of the present unique population study (1989 and 2011) corroborates the necessity for reevaluation of all factors contributing to MetS. Comparison of the two studies depicted clear cut trends of these all-important factors over the years and provide useful conclusions concerning changes in the life style of this population over the years. Limitations of the study include the small number of participants, especially in the number of available blood tests, and the possible errors arising from the use of different measurement instruments during the years 1989 and 2011. Finally, the two populations studied could have substantial differences in the aforementioned metabolic risk factors due to differences in socioeconomic status.[54]

CONCLUSIONS

The present study supports the evidence for the rise of obesity levels and decrease of other biochemical markers and blood pressure in a rural population of adolescents. Obesity levels are worrying as regards the evolution of the syndrome mainly due to the fact that childhood obesity tracks into adulthood. Thus, additional factors that may contribute to the observed trend in obesity prevalence over time must be investigated in future studies.

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CONFLICT OF INTEREST

None of the authors had any potential conflict of interest.

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