Διαχρονικές αλλαγές σε ανθρωπομετρικές μετρήσεις και στην πίεση σε παιδιά στην Κρήτη τις χρονικές περιόδους 1992/93 και 2006/07

Secular changes in anthropometric measurements and blood pressure in children of Crete, Greece, during 1992/93 and 2006/07

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Σκοπός. Να εξετάσει τις διαχρονικές αλλαγές σε ανθρωπομετρικές μετρήσεις και την πίεση σε παιδιά της Α’ τάξης Δημοτικού στην Κρήτη τις χρονικές περιόδους 1992/93 και 2006/07.

Μεθοδολογία. Στην έρευνα συμμετέχαν παιδιά (ηλικίας 5.7–7.8 ετών) από δύο αντιπροσωπευτικές διαστρώσεις κατά τις περιόδους 1992/93 (n=606) και 2006/07 (n=361). Αξιολογήθηκαν τα: Σωματικό βάρος, Δείκτης Μάζας Σώματος (BMI), περιφέρεια μέσης (WC), Αναλογία Μέσης προς Ισχίο (WHpR), Αναλογία Μέσης προς Ύψος (WHtR), πίεση (BP), τεστ παλίνδρομου τρεξίματος 20 µ (20mSRT), και τεστ μέσης προς έντονης φυσικής δραστηριότητας (MVPA).

Αποτελέσματα. Υπήρξε σημαντική αύξηση (P<0.01) στο σωματικό βάρος (+10.2% και +6.7%), BMI (+6.9% and +4.0%), WC (+5.6% και +5.1%), WHpR (+3.0% και +3.4%), και WHtR (+4.2% και +3.8%), για τα αγόρια και
Introduction

Obesity in both children and adults has been recognized in many studies, as an epidemic in most developing countries, with major public health implications, an increased risk for all causes of mortality, and an increased prevalence of cardiovascular disease (CVD) (Rivka and Ronit, 2007; Tambalis et al., 2010). The leading global risks for mortality in the world are high blood pressure (BP) (accounts for 13% of deaths globally), physical inactivity (6%), and overweight and obesity (5%) (WHO, 2009). There is lack of firm evidence linking BP trends to body mass index (BMI) in young children (Chiolero et al., 2007; Snyder et al., 2004). Several other factors that are likely to contribute to high BP in children and adolescents include dietary factors, physical activity (PA), birth weight, and poor sleep quality (Chiolero et al., 2007). Some studies reveal that increases in BP have resulted in the increase in obesity and can progress to adult hypertension (Angelopoulos et al., 2006; Bao et al., 1995; Din-Dzietham et al., 2007; Muntner et al., 2004), although other investigators have revealed the opposite trend in both developed (Kouda et al., 2010; McCarron et al., 2001; McCarron et al., 2002; Watkins et al., 2004) and developing countries (Chiolero et al., 2009b).

In contrast, in Greece, there is a lack of long-term epidemiologic data regarding information on the trends in changes in anthropometric measurements and BP in children. Research evidence of shortterm studies in children indicates that lifestyle factors other than obesity appear to be related to elevated BP (Angelopoulos et al., 2006; Kollias et al., 2009; Lobstein et al., 2004).

The primary question of this study is thus whether the change in obesity in children is accompanied by similar changes in BP. The aim of the study was to explore secular changes of body measurements and BP in first grade students of same age at two time measurement points, academic years 1992/93 and 2006/07.

Methods

The present study analyzed data collected from two representative crosssectional studies conducted among Caucasian Cretan children, registered in the 1st grade during the academic years 1992/93 and 2006/07. Both studies were conducted by the Preventive Medicine and Nutrition Clinic of University of Crete and used multistage stratified random sampling for the selection of participants, based on regional population density and demographic data for both cohorts (Manios et al., 2002; Smpokos et al., 2010).

Children in the 1992/93 study cohort were selected from a total population of 6153 1st-graders
participating in the 6-year, school-based “Cretan Health and Nutrition Education program,” an intervention study focusing on children's diet and PA (Manios et al., 2002). For the purposes of the present study, 323 boys and 283 girls (aged 5.9–7.8 years) were selected (Manios et al., 2002). Children in the 2006/07 cohort were selected from a population of 798 1st, 2nd, and 3rd-graders participating in a 1-year intervention on diet and PA (Smpokos et al., 2010). From this study, 361 1st-graders (199 boys and 162 girls) were selected and matched for gender, age, and area of residence with the 1992/93 cohort. All data in both studies were collected using the same protocols. Informed consent was obtained from all parents and assent from the youngsters. The projects were approved by the Ministry of Education and the Ethics Committee of the University of Crete (Manios et al., 2002; Smpokos et al., 2010).

**Anthropometric measurements**

Weight was measured on calibrated digital scales (Seca 861; Hamburg, Germany) to the nearest 0.1 kg and height was measured to the nearest 0.5 cm with a wall-mounted stadiometer (Seca 225; Hamburg, Germany), without shoes. BMI was calculated as weight divided by height, squared (kg/m2). Waist circumference (WC; measured at the umbilicus level) and hip circumference (HC; measured at the widest point between the hips and buttocks) were measured twice, to the nearest 0.1 cm, with a tape in a vertical plane and with the subject standing and gently breathing out. The mean of the two measurements was recorded. Waist-to-hip (WHpR) and waist-to height (WHtR) ratios were then calculated. Conicity index (CI), a measure of abdominal adiposity relating to abdominal girth, weight, and height, was also calculated as it purportedly offers several advantages over other obesity indices. Conicity is an index of body fat distribution which expresses an individual's waist circumference of a cylinder generated with that person's weight and height, assuming a constant for body density. Theoretically, the value of the index varies between 1.0 (a perfect cylinder) and 1.73 (a perfect biconical shape) (Mueller et al., 1996).

**Physical activity (PA) and physical fitness assessment**

Children’s PA was assessed using an interview-administered standardized questionnaire by both students and parents, for validation purposes. Respondents reported the time spent by children on various activities on two consecutive weekdays and one weekend day. Details on this method's validation have been previously reported (Manios et al., 2002; Smpokos et al., 2010). Activities were classified in three categories according to their intensity, as recommended by Ainsworth et al. (2000): light (b3 METS, e.g., sleeping, watching TV, etc.), moderate (3–6 METS, e.g., cycling, dancing, etc.), and vigorous (N6 METS, e.g., soccer, running, etc.). The questionnaire specifically estimated moderate-to-vigorous physical activity (MVPA; average min/week when children engaged in activities requiring greater energy expenditure than normally needed). The weekly time devoted to activities with intensity higher that 3-METS and duration longer than 30 min was used to determine weekly MVPA.

Cardiorespiratory fitness was assessed by trained instructors during school physical activity classes, using the endurance 20 m shuttle run test (20mSRT). Evaluation of physical fitness was based on the Eurofit test protocols (CESR, 1990).
**Blood pressure**

BP measurements were performed with a mercury sphygmomanometer (FOCAL-FC 110; Tokyo, Japan), after a 10 min rest. The width of the cuff was placed at the highest possible part of the right arm, covering 50%–75% of the area. The measurement was taken three times, with a 2–3 min interval between each reading. The mercury was allowed to fall 2 mm/s. Final readings of systolic (SBP) and diastolic (DBP) blood pressures were taken as the mean values of the second and third measurements.

For the 1992/93 cohort study, BP was measured before the beginning of the educational intervention program. In 2006/07, BP was measured after the completion of the intervention program, which revealed no significant changes in BP measurements between the intervention and the control group of the 1-year program (Smpokos et al., 2010).

**Television viewing**

Data on children's television exposure was collected by asking participants to report the number of hours spent watching television on an average weekday and weekend day. We used these variables to separately determine the average number of hours spent watching television on any day of the 5-weekdays and on the weekend (Kafatos et al., 2005).

**Statistical analysis**

All analyses were performed using SPSS 18.0 (SPSS Inc., Chicago, IL). Chi-square ($\chi^2$), Mantel–Haenszel, and analysis of variance tests were performed to compare gender differences in descriptive characteristics (age, academic year, and place of residence). Prevalence of overweight/obese children was also assessed between genders and academic years with the same methods.

Anthropometric measurements were compared between the two academic years using multivariate analysis of covariance, with age and intervention–control group (randomization in the original studies) as covariates (heterogeneity was tested by Levene's test).

**Table 1.** Descriptive characteristics of the two study samples in relation to gender.
Table 2. Children's anthropometric measurements during 1992/93 and 2006/07.

<table>
<thead>
<tr>
<th></th>
<th>1992/93</th>
<th>2006/07</th>
<th>Δ-difference</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Weight (kg)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>23.9 (1.0)</td>
<td>26.6 (1.0)</td>
<td>+2.7</td>
<td>10.2</td>
</tr>
<tr>
<td>Girls</td>
<td>23.5 (1.0)</td>
<td>25.2 (1.0)</td>
<td>+1.7</td>
<td>6.7</td>
</tr>
<tr>
<td><strong>Height (cm)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>121.7 (0.3)</td>
<td>123.8 (0.4)</td>
<td>+2.1</td>
<td>1.7</td>
</tr>
<tr>
<td>Girls</td>
<td>120.6 (0.4)</td>
<td>122.3 (0.5)</td>
<td>+1.7</td>
<td>1.4</td>
</tr>
<tr>
<td><strong>Body mass index (kg/m²)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>16.18 (1.01)</td>
<td>17.38 (1.01)</td>
<td>+1.20</td>
<td>6.9</td>
</tr>
<tr>
<td>Girls</td>
<td>16.22 (1.01)</td>
<td>16.90 (1.01)</td>
<td>+0.68</td>
<td>4.0</td>
</tr>
<tr>
<td><strong>Waist circumference (cm)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>55.59 (1.01)</td>
<td>58.88 (1.01)</td>
<td>+3.29</td>
<td>5.6</td>
</tr>
<tr>
<td>Girls</td>
<td>54.58 (1.01)</td>
<td>57.54 (1.01)</td>
<td>+2.96</td>
<td>5.1</td>
</tr>
<tr>
<td><strong>Hip circumference (cm)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>64.63 (0.39)</td>
<td>66.62 (0.50)</td>
<td>+1.99</td>
<td>3.0</td>
</tr>
<tr>
<td>Girls</td>
<td>65.31 (0.38)</td>
<td>66.49 (0.51)</td>
<td>+1.18</td>
<td>1.8</td>
</tr>
<tr>
<td><strong>Waist-to-hip ratio</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>0.864 (0.003)</td>
<td>0.891 (0.003)</td>
<td>+0.027</td>
<td>3.0</td>
</tr>
<tr>
<td>Girls</td>
<td>0.841 (0.003)</td>
<td>0.871 (0.004)</td>
<td>+0.030</td>
<td>3.4</td>
</tr>
<tr>
<td><strong>Waist-to-height ratio</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>0.458 (0.003)</td>
<td>0.478 (0.003)</td>
<td>+0.020</td>
<td>4.2</td>
</tr>
<tr>
<td>Girls</td>
<td>0.455 (0.003)</td>
<td>0.473 (0.004)</td>
<td>+0.018</td>
<td>3.8</td>
</tr>
<tr>
<td><strong>Conicity Index</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>1.150 (0.003)</td>
<td>1.166 (0.004)</td>
<td>+0.016</td>
<td>1.4</td>
</tr>
<tr>
<td>Girls</td>
<td>1.135 (0.004)</td>
<td>1.163 (0.005)</td>
<td>+0.028</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Comparisons were performed by using multivariate analysis of covariance, with age and intervention–control group as covariates.

a Log10 transformed values were used in analysis.

b The numbers of children in 1992/03 are as follows: boys, n = 314; girls, n = 275; and in 2006/07 are as follows: boys, n = 193; girls, n = 162.
BP measurements were compared using the same method, with age, intervention–control group, and weight as covariates. Analysis of covariance (with age, gender, and intervention–control group as covariates) was used to compare BP levels among normal weight, overweight, and obese children in the two academic years.

In order to examine linear trends in TV viewing and prevalence of overweight/obesity, TV viewing was divided in three categories (<1.5, 1.5–3.0, and >3.0 h/day), and relationships with BMI and the prevalence of overweight/obese children (IOTF criteria) (Cole et al., 2000) were tested using analysis of covariance and Chi-square test, respectively. Multiple linear regression analysis was used to determine the effect of gender, age, area of residence, intervention–control group, body weight, 20mSRT, and MVPA on SBP and DBP, separately for each academic year.

**Results**

Descriptive characteristics of the study population are shown in Table 1. There were no significant differences in gender distribution, age, and area of residence between the two time periods.

Differences in anthropometric measurements between 1992/93 and 2006/07 are presented in Table 2. In 2006/07, both boys and girls were taller, heavier, and had higher BMI than their peers in 1992/93 (P<0.01). Significant percentage increases between the two time periods were observed in weight, height, and BMI in both genders. The other anthropometric measurements followed a similar pattern, with WC showing the highest percentage increase between the two periods (5.6% and 5.1% for boys and girls, respectively).

Compared to 1992/93, a higher percentage of boys were overweight/obese in 2006/07 (19.4% vs. 33.7%; P<0.001) (Fig. 1).

**Fig. 1.** Changes in prevalence of overweight and obese children between 1992/93 and 2006/07 (IOTF criteria).

The percentage of overweight/obese girls also increased significantly during this period (24.5% vs.
In contrast, both systolic and diastolic BP showed significant percentage decreases between 1992/93 and 2006/07 in both boys (−14.2% and −6.0%; P<0.001, respectively) and girls (−14.7% and −8.1%; P<0.001, respectively) (Table 3).

A significant association between BMI/overweight category and increasing levels of TV watching was found only in 2006/07 (P<0.01) (Table 4). A significant increase in TV watching was noticed for both genders in 2006/07 compared to their peers of 1992/93 (boys: 2.13 vs. 1.81 h/day, respectively, P<0.001; girls: 2.19 vs. 1.82 h/day, respectively, P<0.001) (data not shown). According to multiple linear regression analysis, there was no statistical significant relationship between 20mSRT or MVPA with BP in any of the time periods. There was, however, a significant positive relationship between BP and body weight (P<0.01) (data not shown). A polynomial/linear trend was found between increasing body weight (normal–overweight–obese) and both systolic and diastolic BPs (P for trend, <0.001) during both time periods (Fig. 2).

**Table 3.** Children’s blood pressure during 1992/93 and 2006/07.

<table>
<thead>
<tr>
<th>Academic year</th>
<th>1992/93</th>
<th>2006/07</th>
<th>Δ-difference</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SE)</td>
<td>Mean (SE)</td>
<td>Change%</td>
<td></td>
</tr>
<tr>
<td>Systolic blood pressure (mm Hg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>104.3 (0.6)</td>
<td>91.3 (0.8)</td>
<td>−130−14.2%</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Girls</td>
<td>102.0 (0.7)</td>
<td>88.9 (0.7)</td>
<td>−131−14.7%</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Diastolic blood pressure (mm Hg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>60.4 (0.5)</td>
<td>57.0 (0.6)</td>
<td>−34−6.0%</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Girls</td>
<td>59.8 (0.5)</td>
<td>55.3 (0.6)</td>
<td>−45−8.1%</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Comparisons were performed by using multivariate analysis of covariance, with age, intervention–control group, and weight as covariates.

The number of children in 1992/93 are as follows: boys, n = 295; girls, n = 258; and in 2006/07 are as follows: boys, n = 193; girls, n = 162.

**Table 4.** Children’s body mass index and prevalence of overweight and obesity by TV viewing in 1992/93 and 2006/07.

<table>
<thead>
<tr>
<th>TV viewing (h/day)</th>
<th>P-value</th>
<th>P for trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.5–2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥3.0</td>
<td></td>
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</tr>
</tbody>
</table>

**1992/93**
- Body mass index (kg/m²): 162 (0.0) [166]
- Overweight/obese: 34 (26.5) [374]
- Overweight/obese: 173 (0.3) [168]
- Overweight/obese: 29 (25.5) [31.6]

**2006/07**
- Body mass index (kg/m²): 162 (0.0) [168]
- Overweight/obese: 12 (28.5) [22.6]
- Overweight/obese: 11 (28.6) [22.6]
- Overweight/obese: 8 (19.8) [18.6]

**Values are means (SE) [n]. Comparisons between categories of TV viewing were performed by using analysis of covariance, with age, gender, and intervention–control group as covariates. Heterogeneity was tested by Levene’s test and P for trend was estimated by linear association.**
The striking finding of the present study is the significant increase in obesity indices and anthropometric measurements and the concurrent significant decline in BP that has occurred among Cretan children, aged 5.7–7.8 years, over a 15-year period. These data are in accordance with other studies indicating a decrease in BP over time, such as in the study by McCarron et al. (2002), which showed declining BP trends among individuals living in developed countries, aged 5–34 years, between 1948 and 1998. This decrease in BP over time has also been observed in other small-scale, e.g., the Bogalusa Heart Study among white and black children, aged 7–9 years (Gidding et al., 1995), and large-scale studies, e.g., the Northern Ireland Young Hearts Project (Watkins et al., 2004) and the Japanese children in Iwata (Kouda et al., 2010) studies, which showed that BP levels have decreased in school children over the past 15 years.

Trends in systolic and diastolic blood pressures were not always consistent between studies. For example, it has been reported that increased BMI could account for the rise in SBP noted in school pupils in Minneapolis (Luepker et al., 1999). However, the upward trend in SBP observed in this earlier study was significantly reduced after adjusting for BMI (Luepker et al., 1999). In contrast, BP declined in English boys from 1995 to 1998, despite a concurrent rise in BMI (England, 2006), similar to the present study. In addition, a study in Glasgow University students reported downward trends in BP between 1948 and 1968 following adjustment for age, height, BMI, and socioeconomic status, suggesting that other factors must have a role (McCarron et al., 2001). Our study lacks covariates (dietary habits, salt intake, birth weight, breastfeeding, dairy product consumption, socioeconomic status, etc.) that could have helped explain the observed declining BP trends. It seems, however, that these factors cannot fully explain the observed decrease in BP levels during the study period. Breastfeeding (BF), for example, has been related to lower BP levels in childhood, which can be the result of the low salt and high long-chain polyunsaturated fatty acid content of breast milk (Chiolero et al., 2007).

However, during the 1990s, breastfeeding practices generally did not change substantially in many countries.
worldwide (Chiolero et al., 2007). In Greece, BF rates are among the lowest in the world and far from the goal of the World Health Organization, which promotes exclusive breastfeeding for 6 months. Thus, a positive explanation for the reduction of BP among the children of 2006/07 cannot be easily drawn (Theofilogiannakou et al., 2006). The only trend data for population breastfeeding is from a Greek publication in 1988–1995, which showed that, of 1150 Cretan children, 40.3% and 9.1% were exclusively breastfeeding after a month and at 6 months, respectively (Linardakis et al., 2000).

The beneficial role of PA in BP levels has been well established, particularly in intervention studies, suggesting that moderate-to vigorous aerobic physical activity improves vascular function and reduces BP (Kollias et al., 2009). A recent study in Hong Kong reported a strong association between BP and frequency of structured PA among Chinese adolescents aged 11–18 years (So et al., 2010). In this earlier study, not only students who had structured physical training activities two or more times a week but also those who did not participate in any regular structured exercise sessions, apart from their school physical education lessons, had significantly lower prevalence of hypertension (So et al., 2010). Despite an observed increase in PA among children in our sample, no correlation was found between BP and PA in order to explain the rapid reduction in BP during the examined 15-year period.

There are several limitations in the present study that limit the generalizability of the findings. First, although trained doctors conducted all BP measurements in both time periods and the same sphygmomanometers were used through the study period, we could not assess the inter-observer and intra-observer reliability (Chiolero et al., 2009b). Second, data from only two cohorts were compared. At least one additional measurement—conducted between the two or after the last survey—would have helped evaluate trends with higher confidence (Chiolero et al., 2009a). Finally, prevalence of overweight and obesity, as well as BP levels, were evaluated among a narrow age group (i.e., children aged 5.9–7.8 years) and, therefore, caution should be exercised when extrapolating these findings to other age-groups (Tambalis et al., 2010).

Nevertheless, our findings are consistent with Watkins et al. (2004), the review by McCarron et al. (2002), and Kouda et al. (2010), who reported a decline in BP among children and adolescents in recent years. The substantial declines in BP that have occurred over a 15 year period in young children, aged 5.9–7.8 years, in Crete, Greece, despite a concomitant increase in BMI, other anthropometric measurements, and TV viewing, need further research in order to determine the underlining mechanism. In the future, BP trends should also be analyzed using a life-course perspective such as dietary and physical activity habits during childhood and adolescence, socioeconomic status at different life stages, pregnancy course, and early life characteristics, such as birth weight and breastfeeding (Chiolero et al., 2007).

**Conclusions**

A significant increase in obesity indices and anthropometric measurements was observed in children in Crete between 1992/93 and 2006/07. The concurrent substantial declines in BP that have occurred over this 15-year period may have had their origin in factors related to changes in lifestyle, such as dietary habits or other non dietary factors. The results of this study did not support the hypothesis that the epidemic of overweight in children has resulted in a commensurate increase in BP levels.


(Committee of Experts on Sport Research). The Eurofit tests of physical fitness: VI European Research Seminar. Izmir, Jun 26–30


So, H., Sung, R., Li, A., et al., 2010. Higher exercise frequency associated with lower blood pressure in Hong


