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Secular Trend in Height Mirrors Socio-economic Changes: A Study of Adolescent Population From Zagreb, Croatia

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ABSTRACT The aim of this study was to examine the height in adolescent population of Zagreb (15-19 years) and to evaluate possible impact of war on secular changes from 1990 to 2010. Randomly selected adolescents of both sexes were surveyed three times in that period, in 1990, 1997 and in 2010. Mean heights were compared between sexes as well as between surveys using the One-way ANOVA. ANOVA Tukey HDS post hoc test was used to determine which survey differed from the others. A trend of decline in height was present in all five female age groups. However, the differences were significant only for 15-year-olds, when comparing 1990 to 2010 survey ($p=0.007$). The total mean height in girls, over the 20-year-period, decreased by 17.4 mm ($p<0.001$). In contrast to that, boys´ height did not change in a 20-year period. When put in a broader socio-economic context, the decline in height detected in 1997 might be a result of the worsening of living conditions during and after the Croatian War of Independence (1991-1995). However, regardless of economic stability that was established after the war, the mean age-at-menarche in 2010 declined in comparison to both 1990 and 1997, causing an earlier halt in the growth of long bones and shorter stature. These results are in concordance with recent hypothesis (Dubois et al. 2012) that the influence of the environment on height is less evident in boys than in girls.

INTRODUCTION

Over the last 200 years, changes in physical growth and development of children and adolescents have been systematically monitored throughout the world. Bogin and Keep (1999) traced secular changes over eight thousand years back around the world. Secular changes in Europe and America in particular, are expressed as a consequence of industrialization in the 19th and 20th century. Positive secular trend is detected especially in developed countries, most probably reflecting improved nutritional and health status of these population (Ulijaszek 2001). In some non-European populations such as in India, Ivory Coast, Senegal, Sudan, Burkina Faso and Papua-New Guinea the absence of secular trends has been reported (Ulijaszek 1998). Several studies have demonstrated a sensitivity of secular trend to changes in life standards both over time and between different social groups (Malina 1979; Hauspie et al. 1997; Loesch et al. 2000).

Results of the studies conducted in Zagreb, Croatia, from 1951-1991, suggested intense secular changes in growth and development of children and adolescents (7-19 years). Girls and boys measured in 1973 were significantly higher than their counterparts measured in 1951; for instance, in just 22 years the average height of girls aged 10-14 years increased for approximately 6 centimeters (cm), whereas in 11-15-year-old boys the average height increased for 7-10 centimeters. In 1982 both girls and boys were taller than in 1973, but for no more than 2-3 cm. In 1991 the increase in height was again modest in all age groups of both genders. Namely, for 11-year-old boys it was barely noticeable, while the same age girls' mean height was identical to that in 1982. Generally, in 40-year period the adolescent (14-19 years) girls' height increased for approximately 5 cm, and adolescent boys' height for 7 cm (Prebeg 1998; Prebeg et al. 1995).

In the research conducted in the Croatian region Middle Dalmatia prewar and in first half of the Croatian War of Independence (1991-

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1995), authors reported a growth in the number of overweight children in the first year of the war, and an increase of longitudinal variables in the following year (Rumboldt et al. 1994). They concluded that the growth and development of children in war were differently affected by the quality and quantity of food, the amount of energy consumed and emotional stress caused by war. Jovanovic and collaborators (2003) measured the schoolchildren from Osijek, Croatia, who were directly exposed to the sufferings of war. Their average height in school year 1995/96 was compared with corresponding measurements from 1980/81. They observed a negative secular trend in 7-year-old children, childhood stage at the time of war, who were not deprived of food or water supply but with an emotional stress caused by exile, change of familiar environment and separation from home. The same children were remeasured in 1999/2000, at age of 11, and these results showed that they caught up with the height of children measured in 1980/81. The authors suggested that the stress associated with wartime events caused the delay in growth.

The aim of the study was to examine the height in 15-19 year olds from the population of Zagreb, the capital, in order to evaluate secular changes in height over the last two decades. Adolescents were measured thrice: in 1990, 1997 and 2010. Considering the fact that 1990 survey took part just before the Croatian War of Independence and 1997 survey two years after the official end of the war, the researchers wanted to evaluate possible influence of war-accompanying socio-economic deterioration on height. Twenty years period is long enough to detect secular changes in body dimensions.

MATERIALS AND METHODS

From 1990 to 2010, three surveys of 15-19-year-old randomly selected adolescents from Zagreb, Croatia, were carried out by a team of trained experts from Institute for Anthropological Research. These surveys were conducted with different foci so the number of examinees differs from survey to survey.

The 1990 survey included 523 girls and 563 boys, the 1997 survey 888 girls and 726 boys and the 2010 survey included 399 girls and 406 boys. The adolescents were from both high schools and vocational schools. All of the participants signed informed consent in case that they were legally adults (18+ years) and in case they were under-aged, their parents also signed written permission to participate in this study. The Ministry of Health and Ministry of Science, Education and Sports of the Republic of Croatia approved the study protocol as well as the Ethics Committee of the Institute for Anthropological Research.

Each protocol consisted of an interview designed corresponding to the interest of the particular survey and short anthropometry. Only a subset of the collected data is presented here. Short anthropometry was undertaken following standard International Biological Programme protocol (Weiner and Lourie 1981), using standard equipment. Height was measured to the nearest 1 mm (millimetres) with a wall-mounted stadiometer. For the anthropometric measurements, subjects wore light athletic clothing and no shoes.

Mean values of the analyzed parameters were compared between surveys using the One-way ANOVA. ANOVA Tukey HDS (honestly significant difference) post hoc test of arithmetic means was used to determine which survey differs from the others. All the analyses and plots were performed by SPSS/PASW Statistics 18.0 statistical package for Windows (SPSS Inc., Chicago, IL, USA), with statistical significance set at $p<0.05$. Only exceptions were Figures 3 and 4, created using Stata 10.0 (Stata Corporation, College Station, TX, USA).

RESULTS

Mean height values are presented by surveys and age groups in Table 1 for girls and in Table 3 for boys. In comparison with 1990 data, in 1997 in total girls sample the researchers detected a slight decline in mean height (7.4 mm, p=ns) and in 2010 girls were even shorter than in 1997 (10 mm, $p=0.013$). To summarize, over a 20-year-period the total mean height of girls decreased by 17.4 mm ($p<0.001$) (Table 2). This negative trend was present in all age groups but difference was significant only in 15-year-olds: from 1990 to 2010, they became 26 mm shorter ($p=0.007$). The researchers observed higher values in 16-year-old girls in all three surveys, but with no significant difference in comparison with other age groups. In addition, results are similar even if the researchers take into account only two standard deviations.

Table 1: Mean height (milimeters) in 1990, 1997 and 2010 surveys in girls and differences among the same age groups of the three surveys (ANOVA F)

Age groups	*1990 Survey*			*1997 Survey*			*2010 Survey*			*F (df: 2;1807)*
	N	*Mean*	*SD*	*N*	*Mean*	*SD*	*N*	*Mean*	*SD*	
15±0.5	122	1677.0	57.9	193	1669.1	57.2	80	1651.8	57.9	4.7**
16±0.5	116	1682.5	60.9	225	1672.8	61.1	100	1665.1	60.1	2.2
17±0.5	118	1670.3	66.0	199	1664.6	58.4	110	1658.8	61.1	1.0
18±0.5	115	1670.4	62.3	198	1664.2	63.4	71	1648.9	52.1	2.8
19±0.5	52	1668.3	53.6	73	1658.8	60.8	38	1656.6	52.0	0.6
Total	523	1674.2	61.2	888	1667.0	60.1	399	1656.8	57.7	9.6**

*p<0.05; **p<0.001

Table 2: Anova Tukey HDS post hoc test of mean heights in girls

Age groups	*Survey contrast*					
	Measured between 1997/1990		*Measured between 2010/1990*		*Measured between 2010/1997*	
	Mean differences	*p<*	*Mean differences*	*p<*	*Mean differences*	*p<*
15±0.5	-7.9	0.464	-25.2	0.007	-17.4	0.061
16±0.5	-9.7	0.348	-17.4	0.093	-7.7	0.543
17±0.5	-5.7	0.700	-11.5	0.330	-5.8	0.703
18±0.5	-6.2	0.665	-21.5	0.054	-15.3	0.169
19±0.5	-9.5	0.624	-11.7	0.598	-2.2	0.980
Total	-7.2	0.074	-17.4	0.001	-10.2	0.013

Table 3: Mean height (milimeters) in 1990, 1997 and 2010 surveys in boys and differences among the same age groups of the three surveys (ANOVA F).

Age groups	*1990 Survey*			*1997 Survey*			*2010 Survey*			*F (df: 2;1962)*
	N	*Mean*	*SD*	*N*	*Mean*	*SD*	*N*	*Mean*	*SD*	
15±0.5	119	1762.4	66.2	219	1744.1	74.5	76	1764.4	71.4	3.7*
16±0.5	120	1779.3	66.0	161	1779.9	66.5	94	1782.8	81.6	0.1
17±0.5	112	1791.7	70.0	161	1805.8	70.9	103	1798.2	65.3	1.4
18±0.5	139	1801.2	74.3	131	1799.2	65.4	97	1797.7	72.8	0.1
19±0.5	73	1807.0	65.3	54	1800.6	72.3	36	1808.8	63.2	0.2
Total	563	1793.8	70.1	726	1779.9	74.4	406	1789.1	73.1	5.5**

*p<0.05; **p<0.001

Table 4: Anova Tukey HDS post hoc test of mean heights in boys

Age groups	*Survey contrast*					
	Measured between 1997/1990		*Measured between 2010/1990*		*Measured between 2010/1997*	
	Mean differences	*p<*	*Mean differences*	*p<*	*Mean differences*	*p<*
15±0.5	-18.3	0.066	2.1	0.979	20.3	0.085
16±0.5	0.7	0.997	3.5	0.929	2.9	0.947
17±0.5	14.1	0.224	6.5	0.769	-7.6	0.662
18±0.5	-2.0	0.971	-3.5	0.962	-1.5	0.986
19±0.5	-6.3	0.859	1.8	0.991	8.1	0.841
Total	-14.0	0.004	-4.7	0.616	9.3	0.101

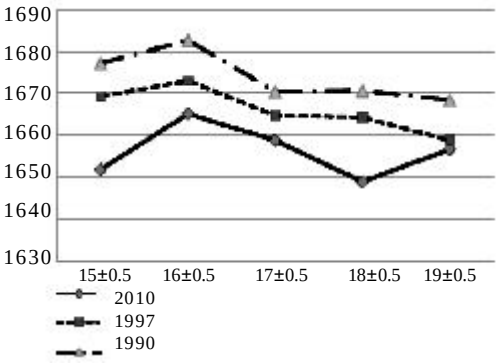

Fig. 1. Changes in mean height in girls over the 20-year period. Total girls' sample is divided into five age groups (15-19-year-olds)

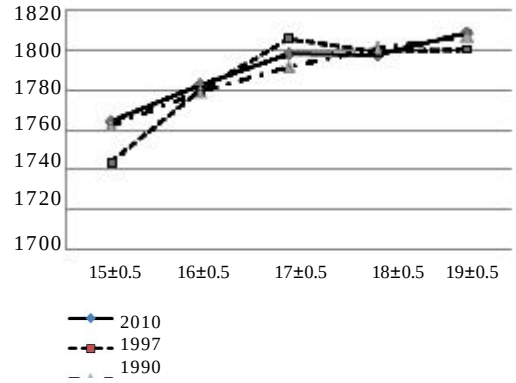

Fig. 2. Changes in mean height in boys over the 20-year period. Total boys' sample is divided into five age groups (15-19-year-olds)

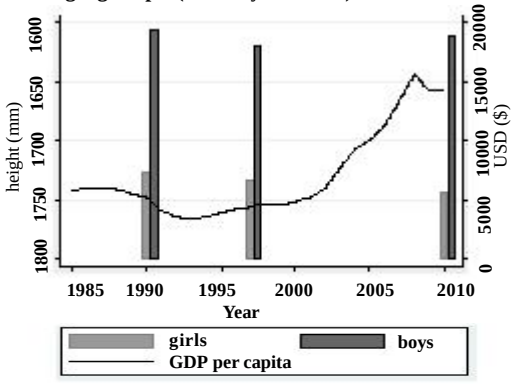

Fig. 3. Secular trend in mean height in adolescent girls and boys in correspondence to changes in Gross Domestic Product (GDP) per capita. GDP per capita data from 1985 to 1999 are taken from Družić (2004), and from 2000 to 2010 from Croatian National Bank bulletin (Vol 168, March 2011)

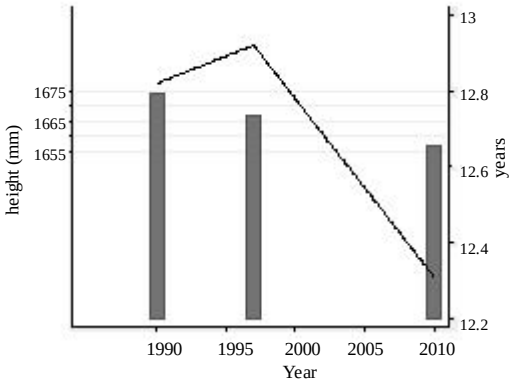

Fig. 4. Secular trend in mean height in adolescent girls in correspondence to mean age-at-menarche

In 1997 boys were almost 14 mm shorter than their counterparts in 1990 ($p<0.004$), but this negative trend did not last: in 2010 mean boys' height increased by 10 mm (p=ns). Only in 15-year-olds this difference was marginally significant: in 1997 they were 18 mm shorter than in 1990, while in 2010 they were 20 mm taller than in 1997 ($p<0.05$, Tables 3 and 4). Trend in mean height for age groups over the 20-year period is visually presented in Figure 1 for girls and Figure 2 for boys.

Data regarding secular trend in the mean height, in correspondence to changes in Gross Domestic Product (GDP) per capita, are shown in Figure 3. GDP per capita was used as a parameter that represented socio-economic conditions in Croatia through 1985-2010 period. After continuous 40-year growth, from 1950 onwards, in 1990 GDP per capita passed through a major downfall followed by a period of rapid growth (Družic 2004). Mean height data, presented systematically for both girls and boys, showed the following: the decrease in GDP per capita line (largest in the last 60 years), coincided with the noticable but statistically insignificant decrease in height of both girls' and boys' (Fig. 3). Improvement in socio-economic situation led to prosperity which had different effects on adolescents: in 2010 we detected increase in boys height in comparison with 1997, while girls' height continued to decline. This decline in height is in concordance with lower mean age-at-menarche in adolescent girls in 2010 (Fig. 4).

DISCUSSION

Genetics and environment are known to influence height (Li and Power 2004). In the inter-

pretation of the results, the researchers have to take into account political and socio-economic changes over the last 25 years in Croatia. Medved (1989) found that Zagreb students in the 1980s were taller than their peers a decade earlier and that their height was comparable with the height of their counterparts from economically most developed countries. However, both prewar socio-economic instabilty and massive damage of country's economic infrastructure during the Croatian War of Independence (1991-1995) affected the living standard. After the War economy stabilized and surge in GDP per capita led to improvement of living conditions with different contribution to height in adolescent boys and girls.

The changes in boys' height from 1990 to 2010 are relatively small and within the range of likely stochastic variations so the researchers presume that they have no important biological meaning. The results suggest that boys' height was not affected by the change in living standard in Croatia which implies that they had reached a plateau in height. In a recent study on genetic and environmental contributions to height, weight and BMI in both sexes from birth to 19 years of age, the authors reported more prominent genetic than environmental impact on height in boys (DuBois et al. 2012). Furthermore, the insensitivity of the males' height to decline in socio-economic stability was detected in modern Spain during the Spanish Civil War (1936–1939). The mean height of Spanish young men (19-21 years) was continuously increasing during the War and in the post-War period, regardless of downfall in GDP per capita in 1936 and maintenance of below pre-War GDP level until 1955 (Ramon and Martinez-Carrion 2010).

Our data on adolescent girls demonstrate a decline in their mean height from 1990 on. The decrease detected in 1997 might have been caused by worsening of living conditions due to the Croatian War of Independence. The height of women who were between 13 and 20 years of age in 1994, during the Rwanda genocide, is much lower than in older cohorts and compared with girls from neighboring countries (Agüero and Deolalikar 2011). The decline in height caused by socio-economic instability was reported after both World Wars in Europe and during the World War II in Japan and Turkey (Malina 1990; Bogin 1999; Cole 2003; Neyzi et al. 1996).

Surprisingly, regardless of the improvement of the after-war Croatian economy from 1996 on and the growth in GDP, the mean girls' height continued to decline.

In order to interpret decrease in height from 1997 to 2010, mean age-at-menarche of these girls was taken into account. In a previously published paper the researchers reported a general trend of decline in the age at menarche in Zagreb adolescent girls from 1990 to 2010 ($p<0.001$), with a statistically insignificant initial increase between 1990 and 1997 (Vecek et al. 2011). The observed trends in adolescents' height, GDP per capita and age at menarche suggest that from 1990 to 1997 height decreased due to the worsening of living conditions (fall in GDP and later onset of menarche), which improved from 1997 on. However, this improvement led to even earlier onset of menarche in 2010 compared to 1990. Previous studies confirmed that girls with earlier menarche reach a shorter adult height compared with girls who have menarche at a later age (Okasha et al. 2001; Onland-Moret et al. 2005). This relation may be explained by the earlier closure of epiphyseal growth disks because of the increase in ovarian estrogens (Helm et al. 1995; Georgiadis et al. 1997).

Results of studies of differences between the sexes in their response to environmental improvement are contradictory (Stinson 1985). Although many studies found that the growth of boys is more sensitive to the environment than the growth of girls, other suggests the opposite. Recently, in an international study of 12,000 twin pairs, it was found that the common environmental factors exert their strongest and most independent influence specifically in pre-adolescent years and more significantly in girls (Dubois et al. 2012).

To conclude, our results are in concordance with recent hypothesis (Dubois et al. 2012) that the influence of the environment on height is less evident in boys than in girls. Furthermore, both worsening of socio-economic parameters and earlier age-at-menarche contribute to decrease in female height.

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