# Secular Change in Body Height and Cephalic Index of Croatian Medical Students (University of Rijeka)

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*KEY WORDS* debrachycephalization; height; secular change

*ABSTRACT* An investigation of body height and cephalic measurements was performed among five groups of first-year medical students of the University of Rijeka School of Medicine (Rijeka, Croatia). Body height and different cephalic measurements showed normal distribution, both in male and female students. Differences between measured variables were statistically analyzed by ANOVA. No significant difference with regard to year of birth was found in either males or females. The cephalic index showed no statistically significant difference between sexes or with regard to body height, while head breadth and length correlated significantly with birth year and body height, both in males and females. Head breadth decreased within the study period, while head length increased. Results were compared with those of similar studies from the mid-20th century. Student's *t*-test showed a significant change of cephalic indices and other head measurements, but not of body height, in males. The frequency difference between various head shapes was tested using the chi-square test. A significant increase of dolichocephalic and mesocephalic and a significant decrease of brachycephalic head shape were found in both sexes. These results suggest a continuity of the debrachycephalization process observed in our population at the past midcentury. Am J Phys Anthropol 123:91–96, 2004. 

The phenomenon of secular acceleration was already reported in earlier studies, and the process of debrachycephalization was observed in the European male population since the beginning of the 20th century (Zellner et al., 1998; Jaeger et al., 1998a; Stolarczyk and Malinovski, Jaeger et al., 1996). The same phenomena were observed in the male population of medical students from Rijeka from year of birth in 1939 till 1963 (Kovač, 1984). The body height of male medical students born in 1955 reached the value of 180.1 cm and, with slight variations, remained constantly above the value of 180 cm. In students born in 1963, body height reached 182.5 cm. Kovač (1984) also pointed out the tendency of debrachycephalization (lower values of cephalic indices), especially in those students born in 1955 and later, associated with a concurrent increase of mean body height in the male student population. We studied body height and the cephalic index in five groups of first-year medical students from the University of Rijeka School of Medicine (Rijeka, Croatia), in order to compare new data with those collected by Kovač (1969, 1984). The aim of our study was to determine the mean height and head measurements of the present generation, and to establish a possible correlation between those variables in the male or female group. We also wanted to determine whether the process of debrachycephalization was continuing in our population.

## SUBJECTS AND METHODS

Our study included 621 first-year students from the University of Rijeka School of Medicine, aged 19–20 (248 male and 373 female), born between 1974–1976, and in 1982 and 1983, divided into groups according to year of birth. They came from different parts of Croatia, all parts being approximatively equally represented in each examined group. Measurements of body height included 621 students, while head measurements were performed on 615 students (243 male and 372 female). All students voluntarily participated in the research. Most of the first-year students were included in the study (69–100%). Since students from all parts of Croatia attend our University, our group could represent a larger student population of the same age. Most of the students come from the northwest (Rijeka and surroundings, 40–50%) (Fig. 1). The south (Dalmatia) and central Croatia, including Zagreb

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**Fig. 1.** Geographic regions of Croatia.

*TABLE 1. Mean body height and cephalic index of male medical students*[1]

| Birth year | Body height | | Cephalic index | |
|---|---|---|---|---|
| | N | X ± SD | N | X ± SD |
| 1939 | 53 | 175.5 ± 7.1 | 53 | 85.4 ± 3.2 |
| 1940 | 45 | 176.2 ± 6.9 | 45 | 84.2 ± 3.0 |
| 1941 | 63 | 177.4 ± 5.9 | 63 | 85.1 ± 3.4 |
| 1942 | 80 | 177.5 ± 5.9 | 80 | 84.9 ± 3.8 |
| 1943 | 84 | 177.5 ± 6.0 | 84 | 85.2 ± 3.8 |
| 1944 | 57 | 177.1 ± 5.6 | 57 | 85.3 ± 3.3 |
| 1945 | 54 | 176.8 ± 5.9 | 54 | 84.9 ± 3.4 |
| 1946 | 70 | 177.3 ± 6.1 | 70 | 83.0 ± 3.6 |
| 1947 | 68 | 176.9 ± 6.6 | 68 | 83.9 ± 3.5 |
| 1948 | 59 | 177.0 ± 6.0 | 59 | 83.5 ± 3.2 |
| 1949 | 55 | 177.0 ± 5.6 | 53 | 84.5 ± 3.2 |
| 1950 | 60 | 176.9 ± 5.9 | 52 | 82.7 ± 3.0 |
| 1951 | 59 | 177.5 ± 5.8 | 56 | 83.8 ± 3.4 |
| 1952 | 49 | 177.3 ± 7.2 | 49 | 83.4 ± 3.3 |
| 1953 | 67 | 177.3 ± 6.0 | 67 | 84.0 ± 3.6 |
| 1954 | 63 | 178.7 ± 5.8 | 63 | 84.6 ± 3.4 |
| 1955 | 66 | 180.1 ± 5.4 | 65 | 82.0 ± 3.7 |
| 1956 | 75 | 178.7 ± 5.9 | 75 | 83.1 ± 3.8 |
| 1957 | 62 | 180.2 ± 7.8 | 62 | 82.8 ± 3.2 |
| 1958 | 54 | 180.8 ± 5.1 | 54 | 83.3 ± 3.0 |
| 1959 | 33 | 179.8 ± 5.3 | 33 | 83.5 ± 3.5 |
| 1960 | 60 | 180.2 ± 5.5 | 58 | 83.7 ± 3.2 |
| 1961 | 28 | 182.0 ± 6.5 | 25 | 81.5 ± 3.6 |
| 1962 | 42 | 180.7 ± 5.2 | 40 | 82.7 ± 3.5 |
| 1963 | 30 | 182.5 ± 6.3 | 29 | 82.1 ± 3.6 |

[1] Data of Kovač (1984).

and the surroundings, are represented with 20–25%, while a smaller number of students come from eastern Croatia (Slavonia, 5–10%).

Body height and head measurements for students born between 1974–1976, in 1982, and in 1983 were analyzed using ANOVA. We also used ANOVA to test regional differences between measured variables among students. We could not use ANOVA for comparison with the earlier generations measured by Kovač (1969, 1984), because her individual data were missing. Kovač (1984) gave mean values and standard deviations for body height and cephalic indices for each birth year only for males (Table 1). For head breadth and length, Kovač (1969) gave group means for both sexes for a 10-year period, and not for each birth year. For that reason, the analysis of the difference of body height and head measurements between our sample and that of Kovač (1969) was performed by Student's *t*-test, using group means and standard deviation values.

The difference between frequencies of different head shapes in our sample compared to the group of Kovač (1969) was statistically analyzed using the Yates corrected chi-square test. To compare the integrated results of Kovač (1969) that presented a period of 10 years, we also put all our subjects into one group, thus presenting a period of 9 years.

The cephalic index was determined using the formula:

$$\text{Cephalic index} = (\text{maximal head breadth} \times 100) \div \text{maximal head length}.$$

Regression analysis was used to test the secular change of body height and head measurements. Coefficients of correlation between those variables and birth year were calculated for both sexes.

## RESULTS AND DISCUSSION

The distribution of body height and cephalic measurements (head breadth, head length and cephalic index) in our sample does not deviate from the normal distribution in both sexes. The ANOVA analysis revealed that body height significantly differs by sex ($P < 0.0001$; df = 1) but not by birth year, in both males and females. An increase of mean body height among first-year male medical students from Rijeka is evident from the year of birth 1955 (Kovač, 1984) (Table 1, Fig. 2), which can probably be attributed to better living conditions and adequate nutrition at the time. In the group of male students born in 1955, the mean body height reached the value of about 180 cm. Further increase was observed in students born in 1961 and 1963 (mean values were 182.0 cm and 182.5 cm, respectively). In our sample, we found higher means for students born in 1976 and 1983, and lower means in those born in 1975 and 1982 (Table 2). The ANOVA analysis of body height distribution in both sexes revealed no dependency on a geographic region of Croatia, and the observed differences between groups most probably represent a normal variation. Figure 2 shows an increase of body height and a decrease of cephalic indices in the male student population during a period of 44 years (with two gaps). The mean cephalic index for males had values above 80 in each of the groups of Kovač (1984), ranging from 85.4 (birth year 1939) to 82.1 (birth year 1963). Our students born approximately

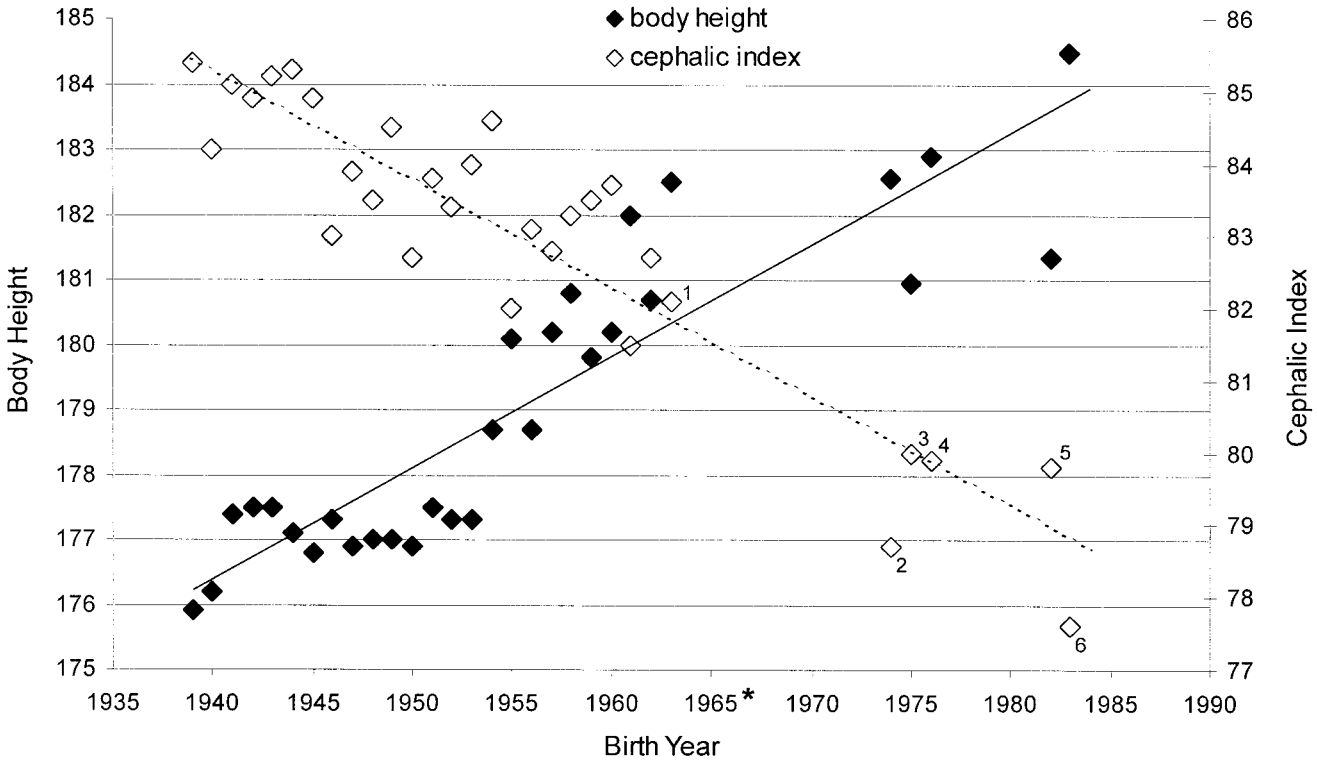


**Fig. 2.** Secular change of body height and cephalic index in male medical students. *Data before 1965 belong to Kovač (1984). Significant difference ($P < 0.001$) between student groups 1 (born in 1963) and 4 (born in 1976). Significant difference ($P < 0.05$) between student groups 1 (born in 1963) and groups 2, 3, 5, and 6 (born in 1974, 1975, 1982, and 1983).

*TABLE 2. Mean body height and cephalic index of medical students (present study)*[1]

| Birth year | Females | | | Males | | |
|---|---|---|---|---|---|---|
| | N | Body height X ± SD | Cephalic index X ± SD | N | Body height X ± SD | Cephalic index X ± SD |
| 1974 | 73 | 169.01 ± 5.65 | 81.80 ± 4.61 | 49 | 182.55 ± 6.71 | 78.72 ± 4.98 |
| 1975 | 93 | 168.64 ± 5.29 | 79.49 ± 6.62 | 53 | 180.96 ± 6.76 | 79.97 ± 5.69 |
| 1976 | 52 | 169.06 ± 7.76 | 78.98 ± 4.75 | 38 | 182.90 ± 5.06 | 79.87 ± 6.22 |
| 1982 | 92 | 168.07 ± 5.82 | 78.75 ± 5.82 | 64 | 181.33 ± 6.78 | 79.75 ± 6.19 |
| 1983 | 63 | 168.79 ± 5.55 | 79.10 ± 5.94 | 44 | 184.48 ± 5.71 | 77.58 ± 4.46 |

[1] Head measurements were made on 243 males and 372 females.

a decade or two later have means around 80 and lower. Females in our sample do not differ significantly from males in cephalic indices (Table 2), but differ significantly in head breadth and length measures ($P < 0.0001$, df = 1 for both variables) (Figs. 3, 4). Regression analysis, used to assess secular change of body height and cephalic index (by regressing stature and cephalic indices to year of birth) in students born in 1974 and later, was negative. In contrast, secular change was observed for head breadth in females ($\beta_{BY} = 0.15$; $P < 0.02$), showing a tendency to decrease with time (Fig. 3). Using ANOVA analysis, we determined that females born in 1974 significantly differ from those born in 1982 ($P < 0.001$; df = 1), and also from those born in 1983 ($P < 0.02$; df = 1). For males, regression analysis revealed significant differences of head length between the examined groups ($\beta_{BY} = 0.15$; $P < 0.05$) (Fig. 4), showing a tendency to increase with time, but not as obviously as the decrease of head breadth in females. An ANOVA analysis showed that males born in 1975 significantly differ from those born in 1982 ($P < 0.05$; df = 1), and the latter also differ from those born in 1983 ($P < 0.02$; df = 1).

The comparison of our measurements with those of Kovač (1969) (Student's *t*-test) revealed significant differences for head length and head breadth values in females and for head breadth in males ($P < 0.02$ or $P < 0.05$) (Table 3). The difference was also significant for cephalic indices between the last group measured by Kovač (1984), born in 1963, and each of our male groups ($P < 0.001$ or $P < 0.05$) (Fig. 2). We also determined the frequencies of different head shapes in our sample, and compared them with frequencies given for earlier generations using the chi-square test. A significant increase of dolichoce-

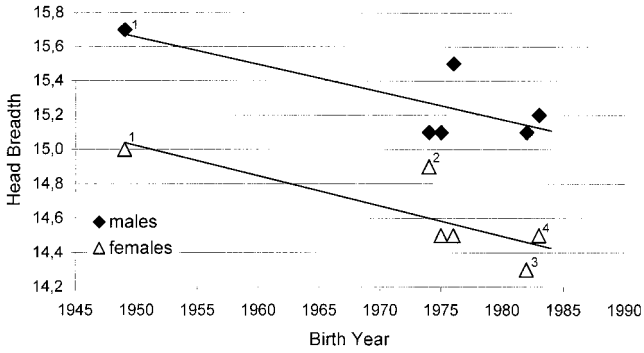


**Fig. 3.** Head breadth of medical students. 1, group mean for 10-year period (1939–1949) (Kovač, 1969). Significant difference ($P < 0.001$) between student groups 2 (born in 1974) and 3 (born in 1982). Significant difference ($P < 0.02$) between student groups 2 (born in 1974) and 4 (born in 1983).

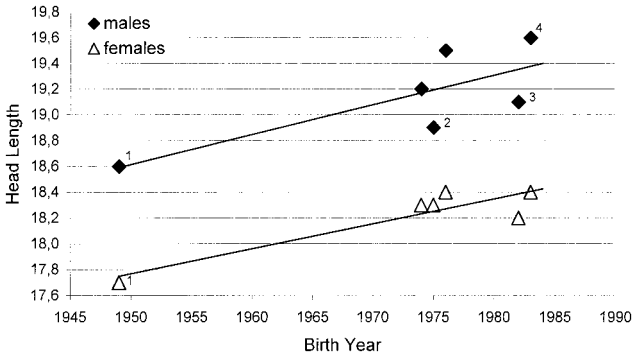


**Fig. 4.** Head length of medical students. 1, group mean for 10-year period (1939–1949) (Kovač, 1969). Significant difference ($P < 0.001$) between student groups 2 (born in 1975) and 4 (born in 1983). Significant difference ($P < 0.05$) between student groups 3 (born in 1982) and 4 (born in 1983).

phalic and mesocephalic head shape and significant decrease of brachycephalic head shape were found in both sexes ($P < 0.001$, df = 2) (Table 4).

Brachycephaly was shown to be a dominant head shape in our population during the first half of the 20th century. The investigation of Kovač (1969) showed that a majority of students (78.9%) had a brachycephalic head, 17.9% were mesocephalic, and only 3.2% were dolichocephalic. Kovač (1969) determined the dolichocephalic head as a feature from southern Croatia (Dalmatia and its islands), while some parts of Croatia were represented with exclusively brachycephalic heads. Rijeka and its surroundings were represented by all cephalic categories. The observed significant changes of overall head shapes are understandable, keeping in mind that Kovač (1969) investigated students born before 1955, the year when the process of debrachycephalization started in our population. Our analysis showed that trends of decrease of head breadth and increase of head length still exist, both in males and females, which resulted in a lowering of cephalic indices. Analyzing the geographic distribution of cephalic indices in our students, we found that regional differences observed years ago by Kovač (1969) still exist (Fig. 5), and are statistically significant (ANOVA, $P < 0.01$; df = 3). The cephalic index has the lowest mean value in the southern part of Croatia, and it significantly differs from means for all other parts of the country ($P < 0.01$ or $P < 0.02$; df = 1) (Fig. 5). The cephalic index values increase to the north and east of the country (Figs. 1, 5). Because frequencies of students from different regions have not significantly changed in our sample, we believe that the regional distribution of our students did not influence the results. In conclusion, the process of debrachycephalization in our student population in general continued towards the end of the 20th century. It is worth mentioning that the mean value of the cephalic index in different parts of Croatia varies, being lowest in the southern Croatian region, where the influence of the Mediterranean climate is the greatest. The mean cephalic index increases to the northwest and especially towards the central and eastern Croatia with the continental climate.

Correlation analysis between measured variables revealed different correlations in sexes (Table 5). Head breadth in females and head length in males significantly correlated with birth year and body height. This would mean that females born later had narrower heads and were shorter, while males became taller and had longer heads. A relatively small sample size in each of our groups probably contributed to the observed different correlations in sexes.

According to many authors, the change of head shape in the past 100 years was influenced by accelerated growth and higher stature, possibly also involving other environmental factors (Kovač, 1984; Jaeger et al., 1998b; Kouchi, Jaeger et al., 2000). Kouchi (2000) pointed out head breadth as the key point in both brachycephalization and debrachycephalization. For northern Mongoloid populations, secular changes of body height were accompanied by a preferential lateral increase of the neural skull growth rate, in contrast to Europeans. For the Japanese, the increase of head breadth and body height shows similar patterns in both sexes, while head length retained similar values over the past century. Consequently, the increase of head breadth was the main cause of changes of cephalic indices. In the European population, head length and breadth were changing continuously and codependently, showing an increase of the former and a decrease of the latter. This was obvious among schoolchildren as well as adults (Zellner et al., 1998, 1999; Gyenis, 1994). Consequently, cephalic indices decreased. These trends of decreased head breadth and increased head length were found among medical students from the University of Rijeka School of Medicine, in the second half of the past century.

Vertical head growth, that is, the increase of brain volume, and of morphological facial and vault height (Jaeger et al., 1998b; Gyenis, Jaeger et al., 1994;

*TABLE 3. Mean head length and head breadth of medical students*

| | Males | | | Females | | |
|---|---|---|---|---|---|---|
| | N | Head length X ± SD | Head breadth[3] X ± SD | N | Head length[3] X ± SD | Head breadth[4] X ± SD |
| Data of Kovač (1919)[1] | 614 | 18.6 ± 4.7 | 15.7 ± 4.4 | 505 | 17.7 ± 4.0 | 15.0 ± 3.7 |
| Present data[2] | 243 | 18.9 ± 1.0 | 15.0 ± 0.9 | 372 | 18.3 ± 0.9 | 14.5 ± 0.8 |

[1] Group mean given for a 10-year period (between 1939–1949).
[2] Group mean given for five examined groups.
[3] Significant difference, $P < 0.02$.
[4] Significant difference, $P < 0.05$.

*TABLE 4. Frequencies of cephalic categories of male and female medical students*

| | Males | | | | | Females | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Kovač[1] | | Present study | | $\chi^2$ | Kovač[1] | | Present study | | $\chi^2$ |
| Cephalic category | N | % | N | % | df = 2 | N | % | N | % | df = 2 |
| Dolichocephalic, CI ≤ 76,9 | 25 | 4.1 | 96 | 39.6 | | 11 | 2.2 | 130 | 35.0 | |
| | | | | | 298.1[2] | | | | | 205.9[2] |
| Mesocephalic, 77.0 ≥ CI ≤ 81.9 | 87 | 14.1 | 93 | 38.4 | | 113 | 22.4 | 110 | 29.5 | |
| Brachycephalic, CI ≥ 82.0 | 502 | 81.7 | 54 | 22.0 | | 381 | 75.3 | 132 | 35.5 | |

[1] Year of birth 1939–1949 (Kovač, 1969). CI, cephalic index.
[2] Significant difference, $P < 0.001$.

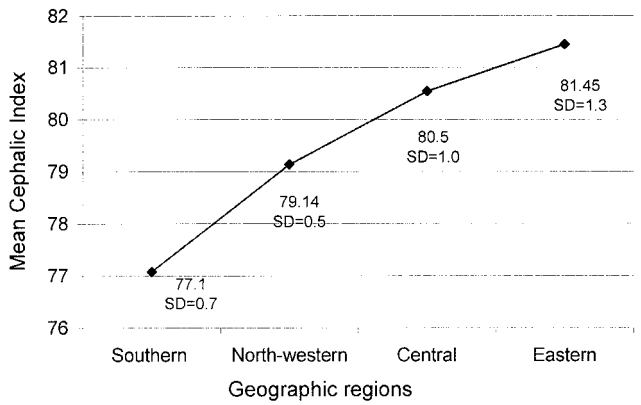


**Fig. 5.** Mean cephalic index in medical students from different geographic regions of Croatia. Value for southern Croatia significantly differs from all other regions ($P < 0.01$, df = 1 for central and eastern region; $P < 0.02$, df = 1 for northwestern region).

*TABLE 5. Correlation coefficients between head measurements and body height of medical students from Rijeka*[1]

| Present study | Correlation coefficients | |
|---|---|---|
| | Males (df = 241) | Females (df = 370) |
| r(CI, Ht) | −0.02 | 0.02 |
| r(HL, Ht) | 0.26*** | 0.14 |
| r(HB, Ht) | 0.12 | 0.15** |
| r(HB, HL) | 0.12 | 0.05 |
| r(CI, By) | −0.09 | −0.12 |
| r(Ht, By) | 0.11 | −0.024 |
| r(HB, By) | 0.03 | −0.15* |
| r(HL, By) | 0.15* | 0.01 |

[1] CI, cephalic index; HL, head length; HB, head breadth; Ht, body height; By, birth year.
* $P < 0.05$.
** $P < 0.01$.
*** $P < 0.001$.

Jantz and Meadows Jantz, 2000), is another important factor affecting changes in head shape in the European population, which was probably crucial for the decrease of horizontal facial measurements and head breadth.

Changes of head dimensions could be more influenced by the environment (climate, nutrition, sleeping position in infancy, migration, and socioeconomic status) (Hoppa and Garlie, 1998; Bharati et al., 2001; Weninger, 1979; Huang et al., 1995; Cvicelova and Klenovicova, 1994; Kouchi, 2000) than by body height. Ferrario et al. (1997) showed a pronounced effect of head form on the three-dimensional facial morphology in axial orientation, which is consistent with the observed vertical growth potential of the neurocranium in Europeans.

Determining further tendencies of body and head growth in our population will require additional research. Vertical head growth tendencies in our student population, and the effects of certain environmental factors (climate and nutrition) on the potential of head growth in different parts of Croatia, will be addressed in our future studies.

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