

# Gender-Specific Growth Patterns for Stature, Sitting Height and Limbs Length in Croatian Children and Youth (3 to 18 Years of Age)

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## ABSTRACT

*In a cross-sectional study of growth, 5,155 children (2,591 females, 2,564 males) from the town of Zagreb (Croatia) were measured. Four traits of linear dimensionality (stature, sitting height, arm and leg lengths) were studied in the age span of 3 to 18 years. A significant average annual increase of all four anthropometric parameters were observed up to 14 and 15 years of age in girls and 16 years of age in boys, showing that girls had a shorter growing period. In the prepubertal period until 9 years of age, gender differences were negligible. At the age of 10, boys were overgrown by girls in all parameters due to the earlier onset of puberty in girls. The growth gains for girls, when compared with those for boys, show a different pattern across variables. The female growth advantage remained in a two years period for the limbs length, but in a three year period for stature and the longest, for 4 years, for sitting height. The male predominance in size had an onset at the age of 13 for the limbs and in the age of 14 for stature and sitting height. The patterns of sexual dimorphism in stature and sitting height during growing years are similar to those observed in other populations of Europe. Growth of Croatian children and youth is very similar to that of the tallest European populations.*

**Key words:** children, growth patterns, gender, morphology, anthropometry, Croatia

## Introduction

Linear body dimensions of children and youth predominantly reflect bone growth, which is especially dramatic in the pubertal period of life<sup>1–4</sup>. These dimensions are closely associated with structural and functional changes. For instance, pubertal height velocity is highly related to the menarcheal age<sup>5</sup> and the slow down of the locomotory system growth with the onset of growth of the respiratory system<sup>6</sup>. As any dynamic system, bone has to maintain a balance of proportions in its permanent change of size and structure. This process is known to be different in males and females during puberty<sup>7</sup>, which can be recognised in the growth channels model described by Živičnjak and Pavičić<sup>2</sup> and Živičnjak et al.<sup>4</sup>.

Although growth of children is too complex to be described by a simple measurement, stature is usually the only parameter used in the assessment of changes in linear body dimensionality. In Croatian children, stature and body weight have been well documented<sup>8–13</sup> but data on other linear measurements from childhood to adulthood are scanty. A detailed description of body morphology in pubertal children from the Croatian town of Zagreb was given by Miličević et al.<sup>14</sup> and Živičnjak et al.<sup>15</sup>. Among numerous measurements, this study recorded stature, sitting height, leg and arm lengths in the age span of 11 to 15 years which was insufficient to reflect fully the linear growth kinetics from childhood to adolescence.

Since statural growth results from changes in length of upper and lower body segments with age, it is indispensable to include sitting height and limbs length in the analysis of growth. The patterns of relative growth of trunk and lower extremities vary among populations. While accepting a strong environmental component for body size, most authors have opted for genetic control of body pro-

portions. It has been recognised recently that environmental factors influence body shape as well<sup>16–19</sup>. The changes of body proportions under the influence of improved quality of life are well documented in the Japanese<sup>20</sup> and Polish<sup>21</sup> populations. In contrast to the trunk and legs, the relative growth of arms has been poorly documented and there are scarce data on its sexual dimorphism and variability among populations.

Considering the importance of knowledge about growth of linear body dimensions in different populations for understanding human morphological variation, the aim of the present study was twofold: (1) to examine the patterns of growth in stature, sitting height and limbs length in Croatian children and youth, and (2) to analyse gender differences in growth of linear body dimensions in this population.

## Subjects and Methods

The study was carried out in the population of the town of Zagreb, the capital of Croatia which constitutes one fourth of the total population of the country. Data have been collected in 5 primary and 4 secondary schools from April to June 1997. Additionally, children in 4 kindergartens were measured in March and May 2000 and 2001. Schools and kindergartens were chosen in different parts of Zagreb representing various socio-economic conditions. Thus, a cross-sectional sample of 5,155 children (2,591 females, 2,564 males) aged 3 to 18 years was measured. Children with chronic disease as well as disabled children were excluded from the study. The sample represents over 5% of the total Zagreb population of children in the age span of 3 to 18 years. Informed consent was obtained in each case and approval of the local ethics committee was given prior to the study. Thus, the study was in accordance with the eth-

ical standards of the Helsinki declaration of 1975 (revised in 1983).

The data used in this study are a subset of the database of the Institute for Anthropological Research, Zagreb that comprises measurements of 28 anthropometrical traits of Zagreb children and youth. The measurements were taken by the examiners who have passed a two-month training led by one of the authors (M. Ž.) prior to the study. Each examiner measured a subset of traits, the same one in the entire sample of children. In case of illness of an examiner, a trained substitute was provided so that maximally two examiners were responsible for each measurement, which kept the inter-observer variance as small as possible. The measurements analysed in the present study consisted of standing height (stature), sitting height, total arm length (arm

length) and height of anterior superior iliac spine (leg length). The maximal inter-observer difference was below 4 mm for stature and 6 mm for sitting height, arm and leg lengths. Measurements were taken according to the IBP recommendations<sup>22</sup> using standard equipment. The accuracy of the measurements was 1 mm. The age cohorts were defined chronologically (e.g. the ages of 10.00 to 10.99 years as the age cohort of 10 years).

Descriptive statistics was used to present substantial characteristics of the data. Comparisons between genders and between successive age cohorts were carried out by means of univariate analysis of variance (ANOVA). The age-related changes were tested using post hoc multiple comparison (the least significant difference – LSD).

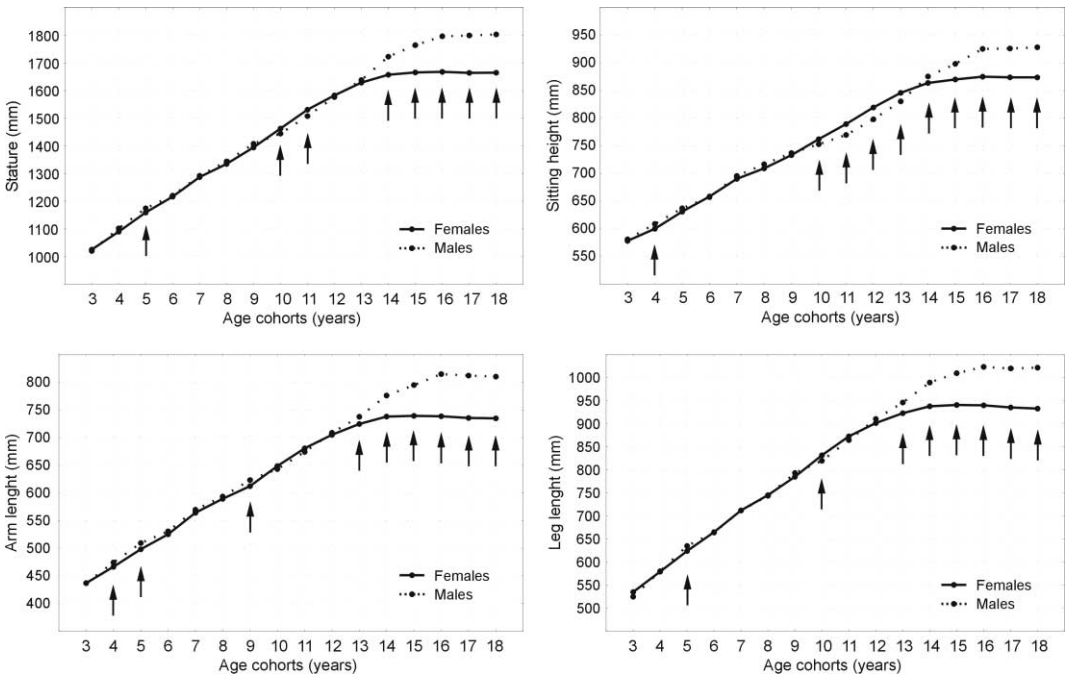


Fig. 1. Distance curves of linear body dimensions (↑ denotes a significant difference between males and females. See Tables 1 to 4).

**Results**

Descriptive statistics of stature, sitting height, arm and leg lengths are shown by age cohorts in Tables 1 to 4. Sample sizes (N), means ( $\bar{X}$ ), standard deviation (SD), standard errors of means (SE), 95% confidence intervals for means

(95% CI), minimal (Min) and maximal (Max) values and coefficients of variation (CV) are given. Plots of the means by age and sex are shown in Figure 1. Statistically significant differences between male and female means obtained using ANOVA are marked by asterisks in tables and by arrows in Figure 1.

**TABLE 1**  
STATURE (IN MM) BY SEX AND AGE

| Age cohort (years)   | N   | $\bar{X}$ | SD   | SE  | 95% CI  |         | Min  | Max  | CV   |
|----------------------|-----|-----------|------|-----|---------|---------|------|------|------|
|                      |     |           |      |     | L Bound | U Bound |      |      |      |
| <b>Females</b> 2,591 |     |           |      |     |         |         |      |      |      |
| 3                    | 39  | 1025      | 41.3 | 6.6 | 1012    | 1038    | 926  | 1097 | 4.03 |
| 4                    | 62  | 1090      | 40.0 | 5.1 | 1080    | 1100    | 982  | 1178 | 3.67 |
| 5                    | 97  | 1159*     | 53.6 | 5.4 | 1148    | 1170    | 1005 | 1325 | 4.62 |
| 6                    | 114 | 1217      | 50.3 | 4.7 | 1207    | 1226    | 1076 | 1334 | 4.14 |
| 7                    | 175 | 1287      | 58.6 | 4.4 | 1279    | 1296    | 1155 | 1452 | 4.55 |
| 8                    | 143 | 1335      | 63.2 | 5.3 | 1325    | 1345    | 1153 | 1513 | 4.73 |
| 9                    | 179 | 1395      | 69.1 | 5.2 | 1385    | 1405    | 1215 | 1560 | 4.95 |
| 10                   | 161 | 1463*     | 68.2 | 5.4 | 1452    | 1474    | 1320 | 1690 | 4.66 |
| 11                   | 208 | 1531***   | 71.6 | 5.0 | 1521    | 1541    | 1342 | 1703 | 4.68 |
| 12                   | 181 | 1583      | 74.7 | 5.6 | 1572    | 1594    | 1398 | 1781 | 4.72 |
| 13                   | 189 | 1629      | 66.0 | 4.8 | 1620    | 1639    | 1446 | 1790 | 4.05 |
| 14                   | 209 | 1658***   | 61.5 | 4.3 | 1649    | 1666    | 1502 | 1844 | 3.71 |
| 15                   | 259 | 1666***   | 60.0 | 3.7 | 1659    | 1673    | 1544 | 1880 | 3.60 |
| 16                   | 227 | 1668***   | 62.5 | 4.2 | 1660    | 1676    | 1483 | 1840 | 3.75 |
| 17                   | 183 | 1664***   | 58.5 | 4.3 | 1656    | 1673    | 1540 | 1826 | 3.51 |
| 18                   | 165 | 1665***   | 64.4 | 5.0 | 1655    | 1675    | 1511 | 1841 | 3.87 |
| <b>Males</b> 2,564   |     |           |      |     |         |         |      |      |      |
| 3                    | 47  | 1020      | 44.3 | 6.5 | 1007    | 1033    | 939  | 1142 | 4.34 |
| 4                    | 90  | 1102      | 40.2 | 4.2 | 1094    | 1110    | 1023 | 1188 | 3.65 |
| 5                    | 119 | 1175      | 49.3 | 4.5 | 1166    | 1183    | 1023 | 1285 | 4.19 |
| 6                    | 112 | 1220      | 50.5 | 4.8 | 1211    | 1230    | 1090 | 1367 | 4.14 |
| 7                    | 191 | 1292      | 57.5 | 4.2 | 1284    | 1300    | 1170 | 1455 | 4.45 |
| 8                    | 153 | 1344      | 66.1 | 5.3 | 1333    | 1355    | 1201 | 1517 | 4.92 |
| 9                    | 177 | 1408      | 61.7 | 4.6 | 1399    | 1417    | 1179 | 1561 | 4.38 |
| 10                   | 182 | 1445      | 61.0 | 4.5 | 1436    | 1454    | 1277 | 1602 | 4.22 |
| 11                   | 225 | 1508      | 72.5 | 4.8 | 1499    | 1518    | 1320 | 1683 | 4.81 |
| 12                   | 213 | 1577      | 89.0 | 6.1 | 1565    | 1589    | 1352 | 1824 | 5.65 |
| 13                   | 217 | 1639      | 85.7 | 5.8 | 1627    | 1650    | 1460 | 1936 | 5.23 |
| 14                   | 225 | 1723      | 74.8 | 5.0 | 1713    | 1733    | 1534 | 1907 | 4.34 |
| 15                   | 198 | 1765      | 69.7 | 5.0 | 1755    | 1775    | 1576 | 1952 | 3.95 |
| 16                   | 145 | 1797      | 66.0 | 5.5 | 1786    | 1808    | 1635 | 2015 | 3.67 |
| 17                   | 155 | 1800      | 71.4 | 5.7 | 1789    | 1811    | 1642 | 2010 | 3.96 |
| 18                   | 115 | 1804      | 65.8 | 6.1 | 1792    | 1816    | 1672 | 1990 | 3.65 |

Significant difference between males and females obtained using ANOVA:

\*  $p \leq 0.05$ , \*\*  $p \leq 0.01$ , \*\*\*  $p \leq 0.001$

### Stature

The annual increase in stature was significant from early childhood to 14 years of age in girls and to 16 years in boys (post hoc LSD procedure:  $p < 0.05$ ). Both sexes experienced similar increase until 9 years. Boys were slightly taller in this period, but gender difference was significant only in the age of 5 years, when they were 15 mm taller than girls (Table 1, Figure 1). The earlier beginning of pubertal spurt in girls resulted in their statural advantage from 10 to 12 years of age. The differences were significant in the ages of 10 and 11. A larger annual increase in boys starting at the age of 12 is illustrated in Figure 2 by an intersection of the two lines. Consequently, boys were significantly taller from 14 years of age to adult stature. As shown in Figure 3, gender difference increased sequentially from 65 mm in the age of 14 to 139 mm in the

age of 18. The coefficients of variation were the highest slightly before the maximal pubertal growth gain.

### Sitting height

The annual gain in sitting height was significant until the age of 15 years in girls and 16 years in boys (post hoc LSD procedure:  $p < 0.05$ ). The annual increments were similar in both genders until the age of 9 (Table 2, Figures 1 and 2). In the age of 7 to 11 years, the growth velocity increased in girls and decreased in boys resulting in their longer trunks at that period. Boys experienced rapid growth of sitting height in the period of 11 to 13 years of age. Consequently, boys had significantly longer sitting height from the age of 14 to adulthood. The difference between genders increased from 12 mm in the age of 14 to 55 mm in the age of 18 (Figure 3). The greatest dispersion of data

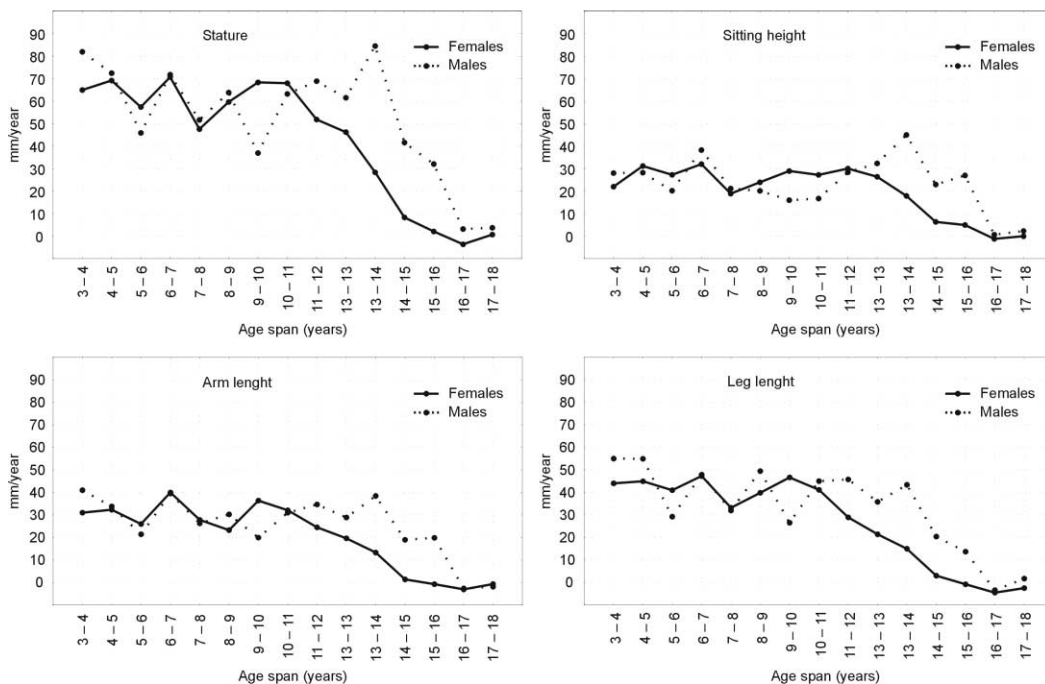


Fig. 2. Velocity curves for linear body dimensions.

TABLE 2  
SITTING HEIGHT (IN MM) BY SEX AND AGE

| Age cohort (years) | N   | $\bar{X}$ | SD   | SE  | 95% CI  |         | Min | Max  | CV   |
|--------------------|-----|-----------|------|-----|---------|---------|-----|------|------|
|                    |     |           |      |     | L Bound | U Bound |     |      |      |
| Females 2,591      |     |           |      |     |         |         |     |      |      |
| 3                  | 39  | 578       | 23.5 | 3.8 | 571     | 586     | 537 | 626  | 4.07 |
| 4                  | 62  | 600*      | 23.0 | 2.9 | 594     | 607     | 544 | 651  | 3.83 |
| 5                  | 97  | 631       | 30.1 | 3.1 | 625     | 637     | 559 | 718  | 4.77 |
| 6                  | 114 | 658       | 30.6 | 2.9 | 653     | 664     | 585 | 738  | 4.64 |
| 7                  | 175 | 690       | 29.6 | 2.2 | 686     | 695     | 606 | 765  | 4.29 |
| 8                  | 143 | 709       | 33.3 | 2.8 | 704     | 715     | 600 | 794  | 4.70 |
| 9                  | 179 | 733       | 36.3 | 2.7 | 728     | 739     | 649 | 818  | 4.95 |
| 10                 | 161 | 762*      | 36.8 | 2.9 | 757     | 768     | 679 | 883  | 4.82 |
| 11                 | 208 | 790***    | 41.5 | 2.9 | 784     | 795     | 695 | 925  | 5.25 |
| 12                 | 181 | 820***    | 42.7 | 3.2 | 813     | 826     | 702 | 930  | 5.22 |
| 13                 | 189 | 846***    | 37.3 | 2.7 | 841     | 851     | 751 | 937  | 4.41 |
| 14                 | 209 | 864**     | 32.3 | 2.2 | 860     | 868     | 773 | 968  | 3.74 |
| 15                 | 259 | 870***    | 30.4 | 1.9 | 867     | 874     | 796 | 969  | 3.50 |
| 16                 | 227 | 875***    | 34.5 | 2.3 | 871     | 880     | 790 | 966  | 3.94 |
| 17                 | 183 | 874***    | 29.6 | 2.2 | 870     | 878     | 795 | 954  | 3.38 |
| 18                 | 165 | 874***    | 34.1 | 2.7 | 869     | 879     | 770 | 958  | 3.90 |
| Males 2,564        |     |           |      |     |         |         |     |      |      |
| 3                  | 47  | 581       | 20.6 | 3.0 | 575     | 587     | 543 | 642  | 3.55 |
| 4                  | 90  | 609       | 24.8 | 2.6 | 604     | 614     | 557 | 669  | 4.07 |
| 5                  | 119 | 637       | 27.2 | 2.5 | 632     | 642     | 573 | 707  | 4.26 |
| 6                  | 112 | 658       | 29.4 | 2.8 | 652     | 663     | 584 | 743  | 4.47 |
| straight 7         | 191 | 696       | 29.7 | 2.2 | 692     | 700     | 625 | 766  | 4.27 |
| 8                  | 153 | 717       | 34.6 | 2.8 | 711     | 723     | 628 | 823  | 4.82 |
| 9                  | 177 | 737       | 30.9 | 2.3 | 733     | 742     | 627 | 806  | 4.19 |
| 10                 | 182 | 753       | 30.3 | 2.2 | 749     | 758     | 667 | 828  | 4.02 |
| 11                 | 225 | 770       | 38.1 | 2.5 | 765     | 775     | 678 | 881  | 4.94 |
| 12                 | 213 | 798       | 45.1 | 3.1 | 792     | 804     | 691 | 933  | 5.65 |
| 13                 | 217 | 831       | 50.6 | 3.4 | 824     | 837     | 710 | 975  | 6.09 |
| 14                 | 225 | 876       | 44.5 | 3.0 | 870     | 882     | 770 | 984  | 5.08 |
| 15                 | 198 | 899       | 39.5 | 2.8 | 893     | 904     | 786 | 990  | 4.39 |
| 16                 | 145 | 926       | 37.2 | 3.1 | 920     | 932     | 810 | 1032 | 4.02 |
| 17                 | 155 | 926       | 40.5 | 3.2 | 920     | 933     | 840 | 1060 | 4.37 |
| 18                 | 115 | 929       | 36.7 | 3.4 | 922     | 935     | 853 | 1010 | 3.95 |

Significant difference between males and females obtained using ANOVA:

\*  $p \leq 0.05$ , \*\*  $p \leq 0.01$ , \*\*\*  $p \leq 0.001$

was observed in both genders in the period of maximal annual change which was earlier in girls (11 to 12 years) than in boys (12 to 14 years) (Table 2).

#### Arm length

Arm increased in length significantly up to the age of 14 years in females and 16 years for males (post hoc LSD proce-

dure:  $p < 0.05$ ). In the prepubertal period, boys had longer arms than girls (significant in the ages of 5, 7 and 9 years) (Table 3, Figure 1). The annual gain in arm length was very similar in both genders leading to nearly equal increase in arm length in the period from 4 to 9 years. Female advantage existed only at the age of 10 and 11 but the difference was negligi-

**TABLE 3**  
ARM LENGTH (IN MM) BY SEX AND AGE

| Age cohort (years)   | N   | $\bar{X}$ | SD   | SE  | 95% CI  |         | Min | Max | CV   |
|----------------------|-----|-----------|------|-----|---------|---------|-----|-----|------|
|                      |     |           |      |     | L Bound | U Bound |     |     |      |
| <b>Females</b> 2,591 |     |           |      |     |         |         |     |     |      |
| 3                    | 39  | 432       | 21.2 | 3.5 | 425     | 439     | 376 | 468 | 4.91 |
| 4                    | 62  | 463*      | 21.8 | 2.8 | 458     | 470     | 411 | 526 | 4.71 |
| 5                    | 97  | 495**     | 25.6 | 2.6 | 490     | 500     | 430 | 567 | 5.17 |
| 6                    | 114 | 521       | 26.5 | 2.5 | 516     | 526     | 445 | 587 | 5.07 |
| 7                    | 175 | 561       | 29.6 | 2.2 | 557     | 566     | 496 | 641 | 5.27 |
| 8                    | 143 | 589       | 33.3 | 2.8 | 583     | 595     | 495 | 690 | 5.66 |
| 9                    | 179 | 612**     | 33.3 | 2.5 | 607     | 617     | 524 | 717 | 5.45 |
| 10                   | 161 | 649       | 34.5 | 2.7 | 643     | 654     | 557 | 761 | 5.32 |
| 11                   | 208 | 681       | 37.1 | 2.6 | 676     | 686     | 580 | 763 | 5.45 |
| 12                   | 181 | 705       | 36.8 | 2.7 | 700     | 711     | 614 | 817 | 5.23 |
| 13                   | 189 | 725***    | 33.8 | 2.5 | 720     | 730     | 642 | 808 | 4.67 |
| 14                   | 209 | 738***    | 29.6 | 2.1 | 734     | 742     | 668 | 827 | 4.02 |
| 15                   | 259 | 739***    | 34.2 | 2.1 | 735     | 744     | 638 | 852 | 4.63 |
| 16                   | 227 | 739***    | 33.0 | 2.2 | 734     | 743     | 634 | 839 | 4.46 |
| 17                   | 183 | 736***    | 31.2 | 2.3 | 731     | 740     | 632 | 800 | 4.25 |
| 18                   | 165 | 735***    | 34.7 | 2.7 | 730     | 740     | 640 | 828 | 4.72 |
| <b>Males</b> 2,564   |     |           |      |     |         |         |     |     |      |
| 3                    | 47  | 431       | 23.1 | 3.4 | 425     | 438     | 381 | 484 | 5.36 |
| 4                    | 90  | 472       | 20.6 | 2.2 | 468     | 476     | 425 | 523 | 4.36 |
| 5                    | 119 | 506       | 24.9 | 2.3 | 501     | 510     | 438 | 557 | 4.93 |
| 6                    | 112 | 527       | 25.6 | 2.4 | 522     | 532     | 459 | 613 | 4.85 |
| 7                    | 191 | 567       | 29.8 | 2.2 | 562     | 571     | 500 | 658 | 5.26 |
| 8                    | 153 | 593       | 32.6 | 2.6 | 588     | 598     | 504 | 698 | 5.49 |
| 9                    | 177 | 623       | 32.6 | 2.4 | 618     | 628     | 502 | 722 | 5.23 |
| 10                   | 182 | 643       | 30.4 | 2.3 | 639     | 648     | 580 | 748 | 4.73 |
| 11                   | 225 | 674       | 36.9 | 2.5 | 669     | 679     | 586 | 772 | 5.47 |
| 12                   | 213 | 709       | 45.3 | 3.1 | 703     | 715     | 606 | 849 | 6.40 |
| 13                   | 217 | 738       | 42.3 | 2.9 | 732     | 743     | 646 | 885 | 5.73 |
| 14                   | 225 | 776       | 37.4 | 2.5 | 771     | 781     | 687 | 869 | 4.82 |
| 15                   | 198 | 795       | 34.0 | 2.4 | 790     | 800     | 702 | 894 | 4.28 |
| 16                   | 145 | 815       | 39.6 | 3.3 | 808     | 821     | 718 | 944 | 4.85 |
| 17                   | 155 | 812       | 35.1 | 2.8 | 807     | 818     | 717 | 903 | 4.32 |
| 18                   | 115 | 810       | 33.8 | 3.2 | 804     | 817     | 735 | 909 | 4.17 |

Significant difference between males and females obtained using ANOVA:

\*  $p \leq 0.05$ , \*\*  $p \leq 0.01$ , \*\*\*  $p \leq 0.001$

ble. From the age of 11, arm grew more rapidly in boys (Figure 2) which resulted in their significantly longer arms from the age of 13 on. Figure 3 demonstrates that gender difference increased from 13 mm in the age of 13 to 76 mm in the age of 18. The greatest variation in arm length as shown by the coefficient of vari-

ation, existed slightly before the maximal pubertal spurt in stature (Table 3).

#### *Leg length*

A consecutive significant increase of leg length has been documented until the age of 15 years in girls and 16 years in boys (post hoc LSD procedure:  $p < 0.05$ ).

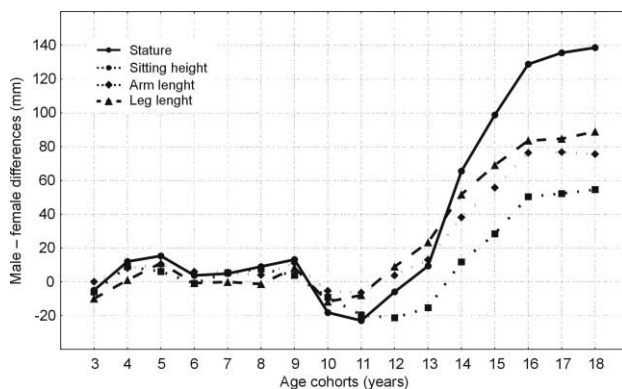


Fig. 3. Gender differences in linear body dimensions by age.

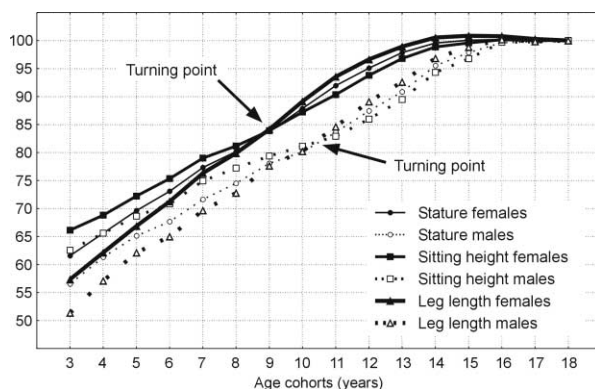


Fig. 4. Percentages of final size achieved during the period of growth.

During the prepubertal period legs grew similarly in both sexes (Table 4, Figure 1). Similarity of boys and girls was maximal in the ages of 6 to 8 years when gender differences did not exceed 1 mm. Due to an increase in leg growth velocity in girls that took place between 8 and 10 years, girls were longer-legged than boys at 10 and 11 years of age (Figures 2 and 3). From the age of 12 on, legs grew more rapidly in boys. Consequently, boys had significantly longer legs from 13 years on. The difference increased from 23 mm in the age of 13 to 89 mm in the age of 18 years (Figure 3). The coefficients of varia-

tion were on the average higher in girls (Table 4). The homogeneity of data was generally marked in childhood and in late adolescence. The greatest variation was observed between mid- and pubertal growth spurts in girls (7 to 9 years) and at 12 years of age in boys (Table 4).

Differing rates of growth in linear body segments can be viewed through the amounts of their final size that are achieved at a given age. Figure 4 illustrates the percentages of final size that were achieved by each linear dimension during growth. The percentages equalled 100% at the age of 18 years. Sexual di-



TABLE 4  
LEG LENGTH (IN MM) BY SEX AND AGE

| Age cohort (years) | N     | $\bar{X}$ | SD   | SE  | 95% CI  |         | Min | Max  | CV   |
|--------------------|-------|-----------|------|-----|---------|---------|-----|------|------|
|                    |       |           |      |     | L Bound | U Bound |     |      |      |
| Females            | 2,591 |           |      |     |         |         |     |      |      |
| 3                  | 39    | 535       | 31.7 | 5.1 | 524     | 545     | 456 | 605  | 5.93 |
| 4                  | 62    | 579       | 24.8 | 3.2 | 573     | 585     | 508 | 641  | 4.28 |
| 5                  | 97    | 624*      | 35.4 | 3.6 | 617     | 631     | 524 | 726  | 5.67 |
| 6                  | 114   | 665       | 34.2 | 3.2 | 658     | 671     | 572 | 734  | 5.15 |
| 7                  | 175   | 712       | 40.3 | 3.0 | 706     | 718     | 637 | 830  | 5.66 |
| 8                  | 143   | 745       | 41.2 | 3.4 | 738     | 752     | 625 | 852  | 5.53 |
| 9                  | 179   | 785       | 45.5 | 3.4 | 778     | 792     | 653 | 906  | 5.80 |
| 10                 | 161   | 832*      | 45.6 | 3.6 | 825     | 839     | 727 | 968  | 5.48 |
| 11                 | 208   | 873       | 47.2 | 3.3 | 866     | 879     | 756 | 980  | 5.41 |
| 12                 | 181   | 902       | 50.2 | 3.7 | 894     | 909     | 783 | 1047 | 5.57 |
| 13                 | 189   | 923***    | 45.3 | 3.3 | 917     | 930     | 799 | 1052 | 4.91 |
| 14                 | 209   | 938***    | 46.1 | 3.2 | 932     | 944     | 819 | 1098 | 4.92 |
| 15                 | 259   | 941***    | 45.6 | 2.8 | 935     | 947     | 827 | 1113 | 4.84 |
| 16                 | 227   | 940***    | 44.9 | 3.0 | 934     | 946     | 817 | 1052 | 4.77 |
| 17                 | 183   | 936***    | 46.2 | 3.4 | 929     | 942     | 820 | 1056 | 4.93 |
| 18                 | 165   | 933***    | 45.2 | 3.5 | 926     | 940     | 822 | 1068 | 4.85 |
| Males              | 2,564 |           |      |     |         |         |     |      |      |
| 3                  | 47    | 525       | 30.8 | 4.5 | 516     | 634     | 470 | 602  | 5.87 |
| 4                  | 90    | 580       | 28.5 | 3.0 | 574     | 586     | 517 | 644  | 4.91 |
| 5                  | 119   | 635       | 32.8 | 3.0 | 629     | 641     | 532 | 705  | 5.17 |
| 6                  | 112   | 664       | 35.1 | 3.3 | 658     | 671     | 570 | 770  | 5.29 |
| 7                  | 191   | 712       | 39.7 | 2.9 | 706     | 718     | 620 | 843  | 5.58 |
| 8                  | 153   | 744       | 44.1 | 3.6 | 737     | 751     | 636 | 845  | 5.92 |
| 9                  | 177   | 793       | 45.3 | 3.4 | 787     | 800     | 647 | 928  | 5.71 |
| 10                 | 182   | 820       | 39.8 | 3.0 | 814     | 826     | 715 | 924  | 4.86 |
| 11                 | 225   | 865       | 50.5 | 3.4 | 858     | 871     | 756 | 1015 | 5.84 |
| 12                 | 213   | 911       | 58.7 | 4.0 | 903     | 918     | 773 | 1065 | 6.44 |
| 13                 | 217   | 946       | 53.4 | 3.6 | 939     | 953     | 833 | 1150 | 5.65 |
| 14                 | 225   | 990       | 48.8 | 3.3 | 983     | 996     | 865 | 1115 | 4.93 |
| 15                 | 198   | 1010      | 47.8 | 3.4 | 1003    | 1017    | 902 | 1138 | 4.73 |
| 16                 | 145   | 1024      | 51.7 | 4.3 | 1015    | 1032    | 875 | 1217 | 5.05 |
| 17                 | 155   | 1020      | 54.5 | 4.4 | 1012    | 1029    | 880 | 1162 | 5.34 |
| 18                 | 115   | 1022      | 48.7 | 4.5 | 1013    | 1031    | 902 | 1136 | 4.76 |

Significant difference between males and females obtained using ANOVA:

\*  $p \leq 0.05$ , \*\*  $p \leq 0.01$ , \*\*\*  $p \leq 0.001$

morphism emerged already at the age of 3. At that time, girls achieved 57.3% of the final leg length and 66.1% of the final sitting height. Boys in this age group achieved lower amounts of final sizes (51.4% and 62.6%, respectively). The female advantage remained throughout the growing period until the age of 16. Rates of growth of different body seg-

ments changed at the time of onset of pubertal growth spurt. Until then, sitting height achieved larger percentages of its final size than did extremities. At the time of onset of the pubertal spurt, the percentages equalised to about 85%. The turning point emerged at the age of 9 in girls and between 10 and 11 years in boys when growth rates of body segments

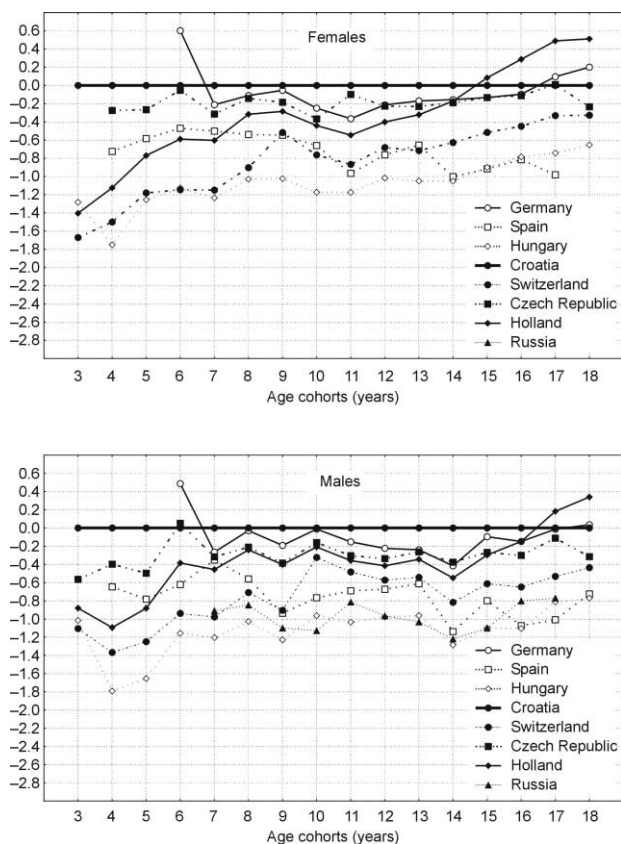


Fig. 5. Stature of Croatian children compared with that of other European populations (SDS values are Z-scores related to the Croatian data).

switched and resulted in changes of body proportions.

The results obtained in all four linear dimensions can be summarized as follows:

- In the prepubertal period, there is an overall similarity in linear dimensions among males and females;
- At the age of 10, boys were overgrown by girls in all parameters. The female growth advantage remained in a two year period for the extremities length, but in a three year period for stature

and a four year period for sitting height;

- During adolescence, differing growth rates of body segments resulted in differential emergence of sexual dimorphism in the studied linear dimensions: at the age of 13 for the extremities, and at the age of 14 for sitting height and stature;
- Growth had longer duration in males than in females: in males, generally until the age of 16, while in females stature and arm length grew until 14

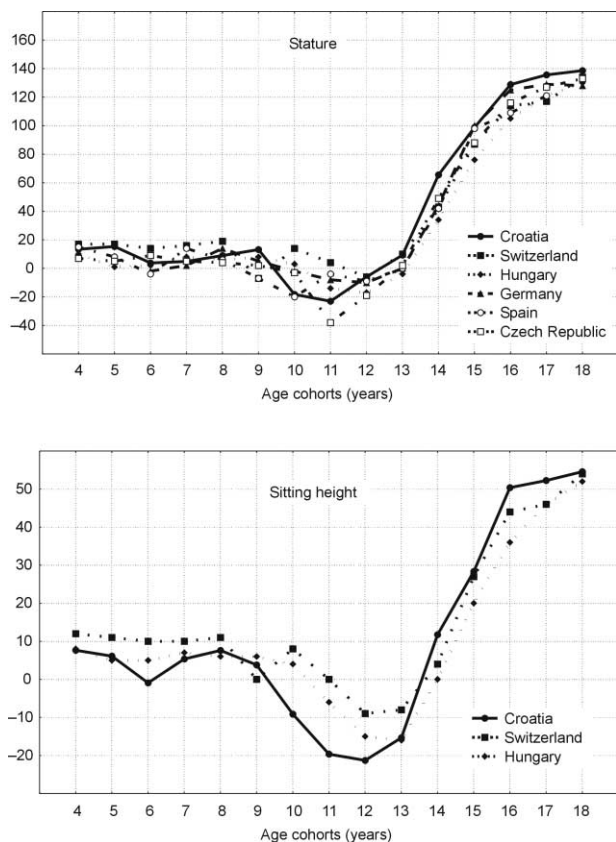


Fig. 6. Gender differences in stature and sitting height for Croatian children compared with other European populations.

years and sitting height and leg length until 15 years age.

### Discussion

This paper contains contemporary cross-sectional data describing the stature, sitting height, arm and leg lengths of children living in the town of Zagreb, Croatia. With the exception of stature, there is generally a lack of referential data on linear body dimensions in healthy children and youth. Even well known studies as the Zürich Longitudinal Growth Study<sup>23</sup>, the Osterwolde Study<sup>24</sup>, the Czech

Nationwide Anthropological Survey<sup>25</sup> or the Hungarian National Growth Study<sup>26</sup> did not include all presently studied characteristics of linear dimensionality. Leg length, if presented, was mostly estimated as a difference of height and sitting height (subischial length), e.g. in the Zürich study<sup>23</sup>. Therefore, the lack of referential data on length of extremities and different measuring techniques restricted comparisons of our data with other studies to stature and sitting height. Standardised values of stature shown in Figure 5 indicate considerable variation in growth among recent European popu-

lations (German<sup>27</sup>, Spanish<sup>28</sup>, Hungarian<sup>26</sup>, Russian<sup>29</sup>, Swiss<sup>23</sup>, Czech<sup>25</sup> and Dutch<sup>30</sup>). They also support Prebeg's<sup>9</sup> view that growth potential of the Croatian population is very similar to that of the tallest European populations. Growth pattern of Zagreb children and youth is most similar to growth of their German and Czech peers.

Measurements of stature and sitting height generally show a similar pattern of sexual dimorphism among populations during the growth period. Gender differences presented in Figure 6 for the Croatian and several other European populations point to the following:

- In prepuberty, until the age of 8 to 9 years, sexual dimorphism in stature and sitting height is negligible in all presented populations. This pattern was noted in the Harpenden study<sup>18</sup> and the Zürich Longitudinal Growth Study<sup>23</sup>, both starting from 3 years of age. Similar effects in statural growth were recognised in other European studies as well, e.g. Slovenian<sup>31</sup>, German<sup>27</sup>, Spanish<sup>28</sup>, Hungarian<sup>26</sup> and Czech<sup>25</sup>;
- In puberty, sexual dimorphism in stature and sitting height markedly differs among populations due to the variation in timing and intensity of the morphological changes;
- In late adolescence, when linear growth is almost completed, there is again a considerable interpopulational similarity in sexual dimorphism despite the fact that its extent is maximal at that period (e.g., for stature: 138 mm in our sample, 128 mm in German<sup>27</sup>, 130 mm in Spanish<sup>28</sup>, 130 mm in Hungarian<sup>26</sup>, 134 mm in the Swiss<sup>23</sup> and Dutch<sup>30</sup>, and 133 mm in Czech<sup>25</sup>).

Throughout the growth period girls achieved larger amounts of final linear size for age (Figure 4) which suggests

their earlier bone maturation. This was documented by the Zürich Study as well<sup>32</sup>.

Although it is impossible to derive the exact dynamics of the growth pattern from cross-sectionally obtained mean growth curves, it is obvious that the adolescent growth spurt has different timings in different parts of the body. The data show that acceleration in leg growth in the late prepubertal and early pubertal periods precede the trunk in both genders (Figures 2 and 4). This is in accordance with the general biological phenomenon that leg length is reaching its peak growth velocity earlier than the trunk<sup>33</sup>. The kinetics of these changes has been described by Gasser et al.<sup>32</sup>, who noted that the pubertal spurt occurred earlier in the legs than in the trunk. Bass et al.<sup>34</sup> confirmed this finding with the statement that appendicular growth was more rapid than axilar growth before puberty in girls. Dasgupta and Das<sup>35</sup> also noted in a cross-sectional growth study of the Calcutta boys that in the age of 16 years legs have almost reached the final size while the trunk is still growing.

The differential growth dynamics of body segments greatly influences changes of body proportions. Legs and stature have similar patterns of growth (especially in the prepubertal period) in both genders stressing stronger dependence of stature on leg length than on sitting height (Figure 2). Recent studies of the effects of quality of life and environmental factors on human growth hypothesised higher plasticity of leg length relative to sitting height. Namely, secular trend toward increased stature observed in numerous populations was found to be almost entirely due to the increase in leg length<sup>36–38</sup>. The trend was associated with better nutritional and health status. It exists in both genders and confirms that environmental factors powerfully influence body shape as well as body size.

Thus, the present observations further illustrate different timing and intensity of change in linear body segments during the growth period. The patterns are gender-specific and result in prominent sexual dimorphism in size and shape of the body in adulthood. The observed changes of body proportions may be a reflection of functional necessity of the organism to achieve skeletal stability and muscle strength in the years of growth. Therefore, growth kinetics of linear body dimensionality has to be studied using different linear traits parallelly. Our study is a contribution in that direction.

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## **OBRASCI RASTA VISINE, SJEDAĆE VISINE I DULJINE UDOVA DJECE I MLADEŽI U HRVATSKOJ (OD 3. DO 18. GODINE ŽIVOTA)**

### **S A Ž E T A K**

U okviru transverzalnog istraživanja rasta djece i mladeži ispitano je 5155 pretškolske djece i učenika (2591 djevojčica i 2564 dječaka) grada Zagreba. Analizirana su četiri pokazatelja linearne dimenzionalnosti tijela (visina, sjedeća visina, duljine ruke i noge) u dobi od 3 do 18 godina života. Mjere tih pokazatelja povećavaju se do 14. i 15. godine u djevojčica te do 16. godine u dječaka što potvrđuje da djevojčice ranije završavaju s rastom. Razlike među spolovima neznatne su u prepubertetskom razdoblju do 9. godine života. Djevojčice ranije ulaze u pubertet i s 10 godina prerastaju dječake. Obrazac rasta pojedinih linearnih dimenzija razlikuje se među spolovima. Prednost djevojčica zadržava se dvije godine za duljine udova, tri godine za visinu i 4 godine za sjedeću visinu. Dječaci prerastaju djevojčice u duljini udova s 13 godina, a u visini i sjedećoj visini s 14 godina. Spolni dimorfizam u razdoblju rasta slijedi obrasce uočene u drugim europskim populacijama. Rast djece i mladeži u Hrvatskoj sličan je onome zabilježenom u najvišim populacijama Europe.