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Gender-Specific Growth Patterns of Transversal Body Dimensions in Croatian Children and Youth (2 to 18 Years of Age)

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ABSTRACT

In a cross-sectional study of growth, 5,260 healthy children of both sexes from Zagreb (Croatia) aged 2 to 18 years were measured. Six transversal body dimensions were studied: biacromial, transverse chest, antero-posterior chest, biiliocristal, bicondylar humerus and bicondylar femur diamters. A significant increase in body diameters has been observed until the age of 14 to 15 in girls and until the age of 16 in boys, showing that girls have a 1 to 2 years shorter period of growth. Compared to boys of the same age, they achieved larger amounts of final transversal bone size throughout the whole growth period. The most pronounced example was the knee diameter that in girls attained 95% of adult size as early as the age of 10. In both genders, the adult size is achieved earlier in widths of the extremities than in those of the trunk. The studied transversal body segments showed different growth dynamics, which is gender-specific. While sexual dimorphism in pelvic and shoulder diameters emerged with pubertal spurt, gender differences in chest and extremities' diameters started early in life. In all ages, boys had larger chest, elbow and knee diameters. In pubertal age boys gained a significantly larger biacromial diameter (from the age of 13 onwards), while girls exceeded them in biiliocristal diameter (from 10 to 14 years). The findings of gender differences were compared to those reported for other European populations and their growth patters were discussed comparing viewpoints.

Key words: *children, growth patterns, gender, anthropometry, transversal dimensions, Croatia*

Introduction

Studies of height and weight changes during the period of human growth have frequently been performed, while changes in transversal body dimensions have not been documented so often. In the Croatian population, the pattern of growth in linear body dimensions and BMI have been well documented from early childhood to adulthood[1–3] but a detailed description of transversal dimensions was given only for pubertal children[4,5]. Hence, in this cross-sectional growth survey an attempt has been made to document the growth pattern in transversal body dimensions of Croatian children with an emphasis on elucidating the gender differences.

The discrepancy in the knowledge about the growth of longitudinal and transversal body dimensions, with far less attention paid to bone growth in width, seems absurd bearing in mind that »…bone growth in length and growth in width have exactly the opposite effects on bone strength – if bones grew only in length without increasing in width, they would become unstable and break at the same point«[6]. Furthermore, optimal growth of bones in width and length during childhood and adolescence plays an important part in the statics of the body and prevention of fractures in late adulthood. Recent studies show that information about the width of bones is essen-

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tial for various applications including: differential diagnosis[7], insight in etiology and patophysiology of a number of musculo-skeletal disorders[8], assessment of treatment efficiency in pediatrics[9,10] or sex determination in forensic science[11,12]. Additionally, the knowledge of growth of transversal body dimensions in different populations is important for understanding human morphological variation. Since there are differences in growth patterns between genders that are particularly evident at some ages and less so at others, the aim of the present study was twofold: 1) to examine the dynamics of growth in diameters of the trunk (biacromial, transverse chest, antero-posterior chest, biiliocristal) and extremities (bicondylar humerus, bicondylar femur) in Croatian children and youths in the age range of 2 to 18 years, and 2) to analyze gender differences in growth patterns for these characteristics during childhood and adolescence and to compare them to those reported for other European populations.

Subjects and Methods

Transversal body dimensions were measured cross-sectionally in the sample of 5,260 healthy children (2,648 females; 2,612 males) aged from 2 to 18 years. The data were collected in 9 primary and secondary schools in the city of Zagreb from April to June 1997. Additionally, children in 4 kindergartens were measured in March and May of 2000 and 2001. Zagreb, the capital of Croatia, constantly experiences large-scale immigration from all regions of the country and its population constitutes one quarter of the total population of the country. The sample represents over 5% of the total Zagreb population aged 2 to 18 years. The data are a subset of the database of the Institute for Anthropological Research in Zagreb, which comprises a wider range of anthropometric measurements of Zagreb children and youth. More detailed information about the sample and method of data collection was previously presented[1].

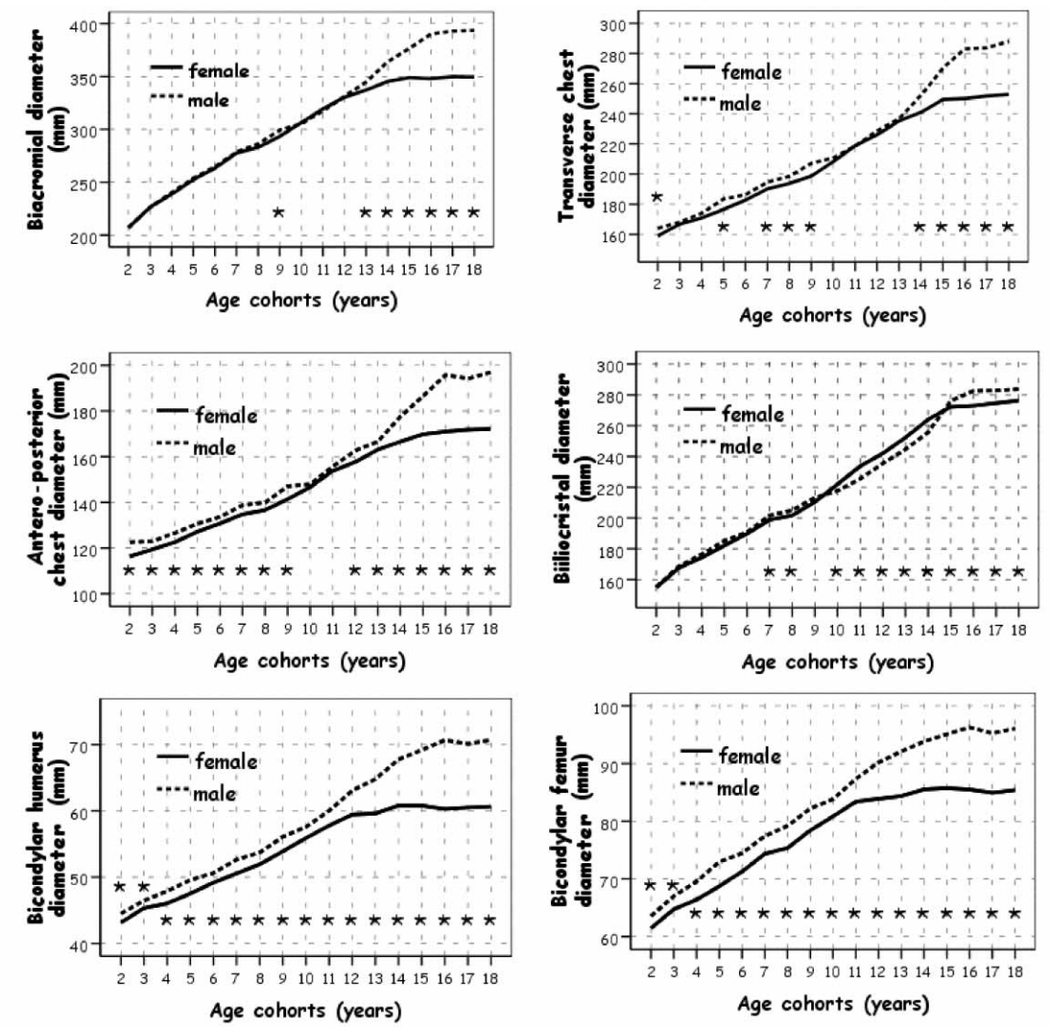

Fig. 1. Distance curves of transversal body dimensions (denotes a significant difference between males and females. See Tables 1 to 6).*

Anthropometric measurements included biacromial, transverse chest, antero-posterior chest, biiliocristal, bicondylar humerus and bicondylar femur diameters. All were taken as recommended by the International Biological Program[13] using the standard equipment (GMP, Swiss). The accuracy of the measurements was 1 mm. The age cohorts were defined chronologically (e.g., 10.00 to 10.99 years as the age cohort of 10 years).

The normality of distribution was evaluated by the Kolmogorov-Smirnov test in each age cohort for each variable. As the distributions did not differ significantly from normal, the parametric methods of analysis were applied. Descriptive statistics was used to present the 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). The Statistical Package for Social Science (SPSS version 14.0) was applied.

TABLE 1
BIACROMIAL DIAMETER (IN MM) BY SEX AND AGE

Age cohort (years)	N	$\overline{X}$	SD	SE	95% CI		Min	Max	CV
					L Bound	U Bound			
Females	2,648								
2	37	206.8	12.0	2.0	203	211	181	229	5.8
3	54	226.5	12.3	1.7	223	230	197	258	5.4
4	62	238.8	11.5	1.5	236	242	218	270	4.8
5	99	252.4	13.8	1.4	250	255	220	295	5.5
6	115	263.3	14.2	1.3	261	266	227	296	5.4
7	177	277.6	13.9	1.0	276	280	246	315	5.0
8	143	283.1	15.5	1.3	281	286	234	318	5.5
9	179	293.4***	17.2	1.3	291	296	241	338	5.8
10	161	306.4	18.9	1.5	303	309	245	353	6.2
11	208	319.4	21.2	1.5	317	322	248	376	6.6
12	181	330.4	20.1	1.5	327	333	275	383	6.1
13	189	337.2***	18.9	1.4	334	340	267	379	5.6
14	209	345.4***	17.2	1.2	343	348	284	391	5.0
15	259	349.0***	17.1	1.1	347	351	295	397	4.9
16	227	348.0***	17.1	1.1	346	350	299	390	4.9
17	183	349.8***	18.9	1.4	347	353	292	396	5.4
18	165	349.5***	16.5	1.3	347	352	302	393	4.7
Males	2,612								
2	33	207.3	11.6	2.0	203	211	180	230	5.6
3	61	226.2	10.0	1.3	224	229	207	247	4.4
4	91	240.3	10.8	1.1	238	243	215	261	4.5
5	119	253.8	13.3	1.2	251	256	225	301	5.2
6	112	264.6	14.6	1.4	262	267	232	302	5.5
7	191	278.7	14.3	1.0	277	281	228	315	5.1
8	152	286.2	14.9	1.2	284	289	251	323	5.2
9	179	299.4	18.0	1.3	297	302	238	349	6.0
10	182	305.5	15.8	1.2	303	308	266	368	5.2
11	225	317.4	18.9	1.3	315	320	255	375	5.9
12	213	331.4	23.7	1.6	328	335	276	396	7.1
13	217	344.8	22.3	1.5	342	348	289	400	6.5
14	225	364.0	22.2	1.5	361	367	295	419	6.1
15	198	376.7	22.5	1.6	374	380	302	425	6.0
16	145	390.2	20.0	1.7	387	394	336	465	5.1
17	155	393.0	20.9	1.7	390	396	330	453	5.3
18	114	393.7	21.2	2.0	390	398	315	445	5.4

Significant difference between males and females obtained using ANOVA: * $p<0.05$; ** $p<0.005$; *** $p<0.001$

Results

Descriptive statistics of six studied diameters in girls and boys are shown in Tables 1 to 6. For each age cohort, the sample size (N), mean ($\overline{X}$), standard deviation (SD), standard error of mean (SE), 95% confidence interval for mean (95% CI), minimal (Min) and maximal (Max) values and coefficient of variation (CV) are given. For each diameter, the distance curves are presented in Figure 1 and velocity curves in Figure 2. Gender differences in each diameter expressed in absolute (mm) as well as in relative (%) terms are shown in Figure 3.

Biacromial diameter

The annual increase in biacromial diameter was significant from early childhood until the age of 15 years in females and 16 years in males. Thereafter, it changed slightly until the age of 18 years: 0.5 mm in females and 3.5 mm in males (Figure 2). The prepubertal annual gain was very similar in both genders. It was the highest from 2 to 3 years of age (19 mm in both genders) and the lowest from 7 to 8 years (5.5 mm in girls and 7.6 mm in boys), leading to nearly equal values in the period from 2 to 8 years (Table 1, Figure 1). Although boys had broader shoulders during pre-puberty, sexual dimorphism was significant only at the age of 9 years when the annual gain was 13.2 in boys vs. 10.3 mm in girls (Table 1, Figure 2). A slight advantage of girls appeared at the age of 10 to 11 (1 and 2 mm, respectively), whereas the advantage of boys gradually increased from 12 to 18 years (from 1 to 44 mm, respectively) (Figure 3). The difference was significant from 13–18 years as a result of gender differences in pubertal growth. Biacromial pubertal spurt became evident earlier in girls, but it lasted longer

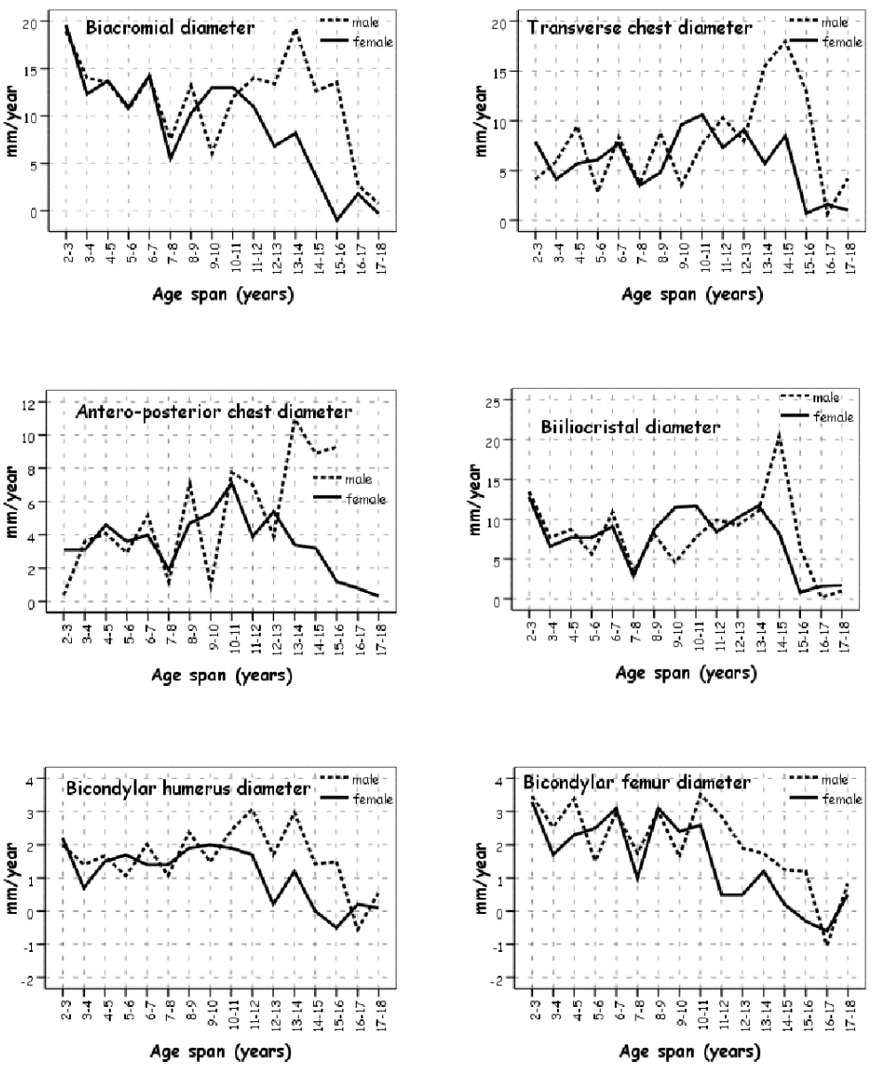

Fig. 2. Velocity curves for transversal body dimensions.

in boys who had a higher growth velocity (19 mm at the age of 13 to 14 years) than in girls (13 mm at the age of 10 to 12 years).

Transverse chest

Transversal chest diameter increased significantly in early childhood, from 2 to 3 years of age in girls and from 4 to 5 years in boys. A further significant gain was documented from 5 to 15 years in girls and from 6 to 16 years in boys. After this age, the growth slowed down and the chest diameter gradually increased until the age of 18 years for 3.2 mm in girls and 4.8 mm in boys (Figure 2). Boys had a constantly broader chest (Table 2, Figure 1). The gender differences were significant in early childhood (ages of 2 and 5 years), in late prepubertal period (7 to 9 years of age) and in adolescence (14 to 18 years). The difference was slight from 11 to 13 years (up to 2.6 mm)

TABLE 2
TRANSVERSE CHEST DIAMETER (IN MM) BY SEX AND AGE

Age cohort (years)	N	$\overline{X}$	SD	SE	95% CI		Min	Max	CV
					L Bound	U Bound			
Females	2,638								
2	37	160.0*	8.3	1.4	156	162	146	181	5.2
3	44	166.8	9.6	1.5	164	170	147	195	5.8
4	62	171.0	10.5	2.1	167	175	150	192	6.1
5	99	176.6**	11.0	1.7	173	180	155	203	6.2
6	115	182.7	10.1	1.2	180	185	157	214	5.5
7	177	190.4***	11.8	0.9	189	192	164	228	6.2
8	143	193.8***	12.7	1.1	192	196	156	246	6.6
9	179	198.7***	13.9	1.0	197	201	160	242	7.0
10	161	208.3	16.2	1.3	206	211	168	256	7.8
11	208	218.8	18.0	1.2	216	221	179	267	8.2
12	181	226.1	19.8	1.5	223	229	176	280	8.8
13	189	235.2	17.5	1.3	233	238	189	290	7.5
14	209	240.9***	17.2	1.2	239	243	197	295	7.2
15	259	249.5***	16.1	1.0	247	251	191	304	6.4
16	227	250.1***	13.5	0.9	248	252	220	302	5.4
17	183	251.7***	14.8	1.1	250	254	215	306	5.9
18	165	252.7***	14.8	1.2	250	255	216	291	5.9
Males	2,612								
2	33	164.1	8.6	154	161	167	147	192	5.2
3	61	168.2	7.8	1.1	166	170	150	184	4.6
4	91	174.1	10.6	2.0	170	178	154	197	6.1
5	119	183.5	10.4	1.3	181	186	166	213	5.7
6	112	186.4	11.1	1.5	183	189	163	206	6.0
7	191	194.8	11.9	0.9	193	197	163	230	6.1
8	152	198.4	11.4	0.9	197	200	171	228	5.8
9	179	207.2	13.3	1.0	205	209	173	244	6.4
10	182	210.8	14.5	1.1	209	213	174	272	6.9
11	225	218.5	16.9	1.1	216	221	176	276	7.7
12	213	228.7	20.3	1.4	226	231	186	289	8.9
13	217	236.7	18.5	1.3	234	239	194	287	7.8
14	225	252.2	20.3	1.4	250	255	190	307	8.0
15	198	270.2	18.4	1.3	268	273	214	325	6.8
16	145	283.1	20.2	1.7	280	286	233	352	7.1
17	155	283.7	17.5	1.4	281	287	240	327	6.2
18	114	287.9	20.1	1.9	284<	292	241	332	7.0

Significant difference between males and females obtained using ANOVA: * $p<0.05$; ** $p<0.005$; *** $p<0.001$

and increased gradually thereafter up to 35 mm at the age of 18 (Figure 3).

Antero-posterior chest

Males had a consistently larger antero-posterior chest diameter than females, from early childhood to adulthood; the difference was not significant only at the ages of 10 and 11 years (Table 3, Figure 1). Interestingly enough, in early childhood the annual gain was not significant in either gender. After this period, the chest diameter kept increasing in boys every second year (e.g. 5 to 7, 6 to 8 years) up to the age of 10. From 10 to 16 years of age, the annual gain was significant and thereafter the change became negligible. In females the annual gain was significant from 4 to 15 years of age except for the age of 7 to 8. The increase was not as dramatic as in boys and resulted with a final difference of 25 mm (Figures 2 and 3).

Biiliocristal diameter

The consecutive annual increase in biiliocristal diameter was significant from early childhood until the ages of 15 and 16 in girls and boys respectively. In pre-puberty, until the age of 9 years, males were in slight non-significant advantage in the diameter (Table 5). The gender differences increased thereafter and reached significance. In the period from 10 to 14 years the diameter was larger in females (from 4.2 to 8.3 mm) and after that age in males (~7 mm) (Figures 1 and 3). The final male-female difference seems to be caused by a discrepancy in maximal annual gain of 20.5 mm in males vs. 11.7 mm in females (Figure 2).

Bicondylar humerus

Throughout the growth period the boys had a significantly broader bicondylar humerus diameter than the girls. The difference increased from 1.4 mm at the age of 2 to 10.1 mm at the age of 18 (Table 5, Figures 1 and 3). The diameter increased significantly until the age of 16 in boys and until 14 in girls (Figure 2).

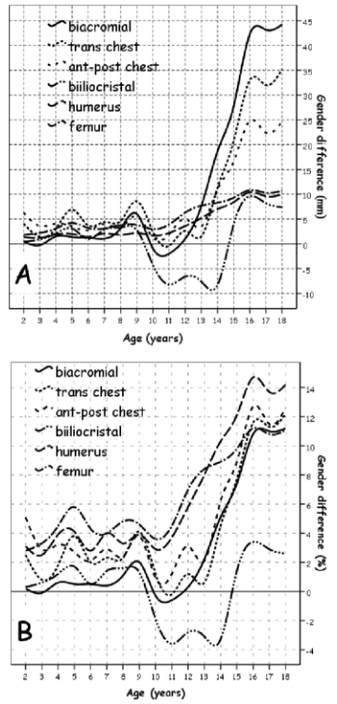

Fig. 3. Gender differences in transversal body dimensions by age;

$$A: \overline{X}_{male} - \overline{X}_{female} (mm),$$

$$B: 100 \times (\overline{X}_{male} - \overline{X}_{female}) / \overline{X}_{male} (\%)$$

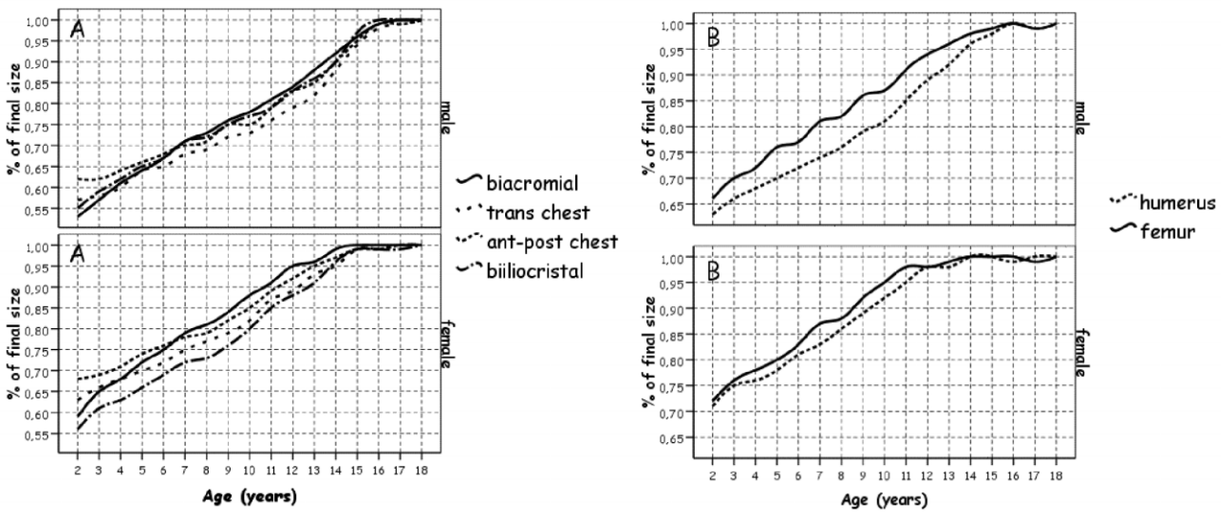

Fig. 4. Percentage of final size achieved during the period of growth; A: truncal diameters; B: extremities' diameters.

Bicondylar femur

The bicondylar femur diameter was continuously significantly larger in boys (Table 6). The difference increased from 1.8 mm at the age of 2 to more than 10 mm after the age of 15 (Figures 1 and 3). The bicondylar femur diameter increased significantly until the age of 16 in boys and until the age of 14 in girls (Figure 2).

Gender differences in transversal body dimensions changed markedly from childhood till adulthood, which is best illustrated by Figure 3. The variables of highest gender similarity at the age of 2 (biacromial and biiliocristal diameter; male – female difference < 1 mm) became in the adult age (18 years) variables of the most important gender feature (Figure 3A). The largest gender difference was observed in biacromial diameter (44.2 mm) and the greatest similarity in biiliocristal diameter (7.4 mm).

The differences expressed in percentages relative to the mail sex enable a comparison of growth dynamic across the diameters (Figure 3B). Bicondylar humerus and femur show similar dynamics of growth as do the diame-

TABLE 3
ANTERO-POSTERIOR CHEST DIAMETER (IN MM) BY SEX AND AGE

Age cohort (years)	N	$\overline{X}$	SD	SE	95% CI		Min	Max	CV
					L Bound	U Bound			
Females	2,648								
2	37	116.3***	5.3	0.9	115	118	106	128	4.6
3	54	119.4*	6.7	0.9	118	121	100	137	5.6
4	62	122.5**	7.4	0.9	121	124	106	142	6.1
5	99	127.2**	8.4	0.8	125	129	106	153	6.6
6	115	130.8*	9.5	0.9	129	133	111	170	7.3
7	177	134.8***	10.6	0.8	133	136	113	164	7.9
8	143	136.7*	10.4	0.9	135	138	110	163	7.6
9	179	141.4***	12.7	1.0	140	143	110	178	9.0
10	161	146.7	14.8	1.2	144	149	115	212	10.1
11	208	153.8	15.2	1.1	152	156	123	204	9.9
12	181	157.7**	15.6	1.2	155	160	121	223	9.9
13	189	163.1*	14.8	1.1	161	165	129	198	9.0
14	209	166.6***	13.2	0.9	165	168	134	208	7.9
15	259	169.8***	13.7	0.9	168	171	132	234	8.1
16	227	171.0***	14.0	0.9	169	173	133	222	8.2
17	183	171.8***	12.0	0.9	170	174	137	201	7.0
18	165	172.1***	13.2	1.0	170	174	134	212	7.7
Males	2,612								
2	33	122.6	5.9	1.0	121	125	113	133	4.8
3	61	123.0	8.3	1.1	121	125	106	147	6.8
4	91	126.6	7.9	0.8	125	128	111	146	6.2
5	119	130.7	9.4	0.9	129	132	108	153	7.2
6	112	133.6	9.2	0.9	132	135	110	159	6.9
7	191	138.8	10.1	0.7	137	140	110	180	7.3
8	152	139.9	10.5	0.9	138	142	116	176	7.5
9	179	147.0	12.8	1.0	145	149	117	192	8.7
10	182	147.9	13.5	1.0	146	150	117	204	9.1
11	225	155.7	15.1	1.0	154	158	128	212	9.7
12	213	162.7	17.9	1.2	160	165	130	222	11.0
13	217	166.6	15.9	1.1	164	169	132	214	9.6
14	225	177.5	17.3	1.2	175	180	141	241	9.8
15	198	186.4	16.8	1.2	184	189	143	251	9.0
16	145	195.7	19.2	1.6	193	199	145	243	9.8
17	155	194.2	15.3	1.2	192	197	156	232	7.9
18	114	196.9	16.7	1.6	194	200	157	248	8.5

Significant difference between males and females obtained using ANOVA: * $p<0.05$; ** $p<0.005$; *** $p<0.001$

ters of the trunk and represent the most important factors of divergence between the genders. In contrast, the biiliocristal diameter exhibits a unique growth dynamics and shows the biggest similarity in adulthood, although it was the parameter of the largest difference in puberty.

Different rates of growth in transversal body segments caused gender differences in size and maturation of the body. Figure 4 illustrates the percentages of final size that were achieved by each diameter during growth. The percentage equaled 100% at the age of 18 years. At the age of 2, girls attained a higher proportion of adult size than boys in all studied diameters. The difference was the greatest in extremities: bicondylar humerus and femur diameters were 71% and 72% of final size in girls vs. 63% and 66% in boys. The smallest difference was noticed in biiliocristal diameter: 56% in girls vs. 57% in boys. Girls reached the final size in all diameters 1 to 2 years earlier than boys. In both genders the adult size is achieved earlier in widths of the extremities than those of the trunk. The most pronounced example was the finding in

TABLE 4
BIILIOCRISTAL DIAMETER (IN MM) BY SEX AND AGE

Age cohort (years)	N	$\overline{X}$	SD	SE	95% CI		Min	Max	CV
					L Bound	U Bound			
Females	2,648								
2	37	154.8	8.8	1.4	152	158	138	174	5.7
3	54	167.7	10.1	1.4	165	170	145	193	6.0
4	62	174.3	8.7	1.1	172	176	158	202	5.0
5	99	182.0	11.6	1.2	180	184	158	228	6.4
6	115	189.7	11.6	1.1	188	192	160	227	6.1
7	177	198.8*	13.8	1.0	197	201	169	250	6.9
8	143	201.7*	14.4	1.2	199	204	163	232	7.2
9	179	210.4	16.8	1.3	208	213	165	271	8.0
10	161	221.9*	17.9	1.4	219	225	176	287	8.1
11	208	233.6***	17.7	1.2	231	236	186	284	7.6
12	181	242.1**	21.9	1.6	239	245	182	309	9.0
13	189	252.3***	18.5	1.3	250	255	201	305	7.3
14	209	264.0***	17.9	1.2	262	266	199	323	6.8
15	259	272.2*	16.2	1.0	270	274	226	326	5.9
16	227	273.0***	15.3	1.0	271	275	213	325	5.6
17	183	274.6***	15.0	1.1	272	277	225	318	5.5
18	165	276.4***	16.8	1.3	274	279	220	329	6.1
Males	2,612								
2	33	155.2	8.2	1.4	152	158	135	170	5.3
3	61	168.6	9.0	1.2	166	171	153	201	5.4
4	91	176.4	10.3	1.1	174	179	153	198	5.8
5	119	185.1	11.7	1.1	183	187	162	218	6.3
6	112	190.7	11.6	1.1	189	193	164	217	6.1
7	191	<201.6	11.7	0.8	200	203	172	231	5.8
8	152	205.0	14.3	1.2	203	207	170	239	7.0
9	179	213.2	17.6	1.3	211	216	169	275	8.2
10	182	217.7	15.8	1.2	215	220	174	267	7.3
11	225	225.5	19.8	1.3	223	228	180	288	8.8
12	213	235.4	22.1	1.5	232	238	181	294	9.4
13	217	244.7	21.6	1.5	242	248	186	302	8.8
14	225	255.7	23.6	1.6	253	259	191	314	9.2
15	198	276.2	17.7	1.3	274	279	216	316	6.4
16	145	282.6	14.8	1.2	280	285	245	321	5.2
17	155	282.8	16.7	1.3	280	285	243	334	5.9
18	114	283.8	17.0	1.6	281	287	239	318	6.0

Significant difference between males and females obta<ined using ANOVA: * $p<0.05$; ** $p<0.005$; *** $p<0.001$

girls who attained 95% of adult size in bicondylar femur and humerus already at the ages of 10 and 11 years respectively.

The gender differences found for six transversal body dimensions can be summarized as follows:

- In all ages, males had a significantly larger bicondylar humerus and femur diameters than females (from 2 to 18 years);
- In pubertal age, boys were significantly overtaken by girls only in the biiliocristal diameter (from 10 to 14 years);
- The gender difference in final size was largest in biacromial diameter and smallest in biiliocristal diameter;
- Growth had a longer duration in males than in females, in males generally until 15 to 16, and in females until 14 to 15 years of age.

TABLE 5
BICONDYLAR HUMERUS DIAMETER (IN MM) BY SEX AND AGE

Age cohort (years)	N	$\overline{X}$	SD	SE	95% CI		Min	Max	CV
					L Bound	U Bound			
Females	2,648								
2	37	43.1*	2.2	0.4	42	44	37	47	5.1
3	54	45.3*	2.5	0.3	45	46	40	52	5.5
4	62	46.0***	2.6	0.3	45	47	39	51	5.6
5	99	47.5***	3.2	0.3	47	48	41	56	6.8
6	115	49.2***	3.2	0.3	49	50	43	59	6.5
7	177	50.5***	3.2	0.2	50	51	44	60	6.4
8	143	51.9***	2.8	0.2	51	52	46	60	5.5
9	179	53.9***	3.4	0.3	53	54	47	64	6.3
10	161	55.9***	3.5	0.3	55	56	48	68	6.2
11	208	57.8***	3.7	0.3	57	58	48	69	6.5
12	181	59.4***	3.4	0.3	59	60	52	69	5.8
13	189	59.6***	3.2	0.2	59	60	52	69	5.3
14	209	60.8***	3.0	0.2	60	61	53	71	5.0
15	259	60.8***	3.0	0.2	60	61	53	69	5.0
16	227	60.3***	3.0	0.2	60	61	52	70	4.9
17	183	60.5***	2.8	0.2	60	61	53	69	4.7
18	165	60.6***	2.7	0.2	60	61	53	70	4.5
Males	2,612								
2	33	44.5	2.4	0.4	44	45	40	49	5.4
3	61	46.5	2.5	0.3	46	47	42	52	5.3
4	91	47.9	2.6	0.3	47	48	42	54	5.4
5	119	49.6	3.0	0.3	49	50	42	57	6.0
6	112	50.6	3.4	0.3	50	51	44	60	6.8
7	191	52.6	3.2	0.2	52	53	45	62	6.2
8	152	53.7	3.3	0.3	53	54	46	64	6.1
9	179	56.1	3.5	0.3	56	57	46	69	6.3
10	182	57.6	3.7	0.3	57	58	50	70	6.4
11	225	60.0	4.0	0.3	59	61	50	72	6.6
12	213	63.1	4.5	0.3	62	64	53	76	7.2
13	217	64.8	4.0	0.3	64	65	53	75	6.1
14	225	67.8	4.1	0.3	67	68	59	79	6.0
15	198	69.2	3.5	0.2	69	70	61	78	5.1
16	145	70.7	3.6	0.3	70	71	62	83	5.1
17	155	70.1	3.6	0.3	70	71	59	79	5.2
18	114	70.7	3.6	0.3	70	71	62	79	5.1

Significant difference between males and females obtained using ANOVA: * $p<0.05$; ** $p<0.005$; *** $p<0.001$

TABLE 6
BICONDYLAR FEMUR DIAMETER (IN MM) BY SEX AND AGE

Age cohort (years)	N	$\overline{X}$	SD	SE	95% CI		Min	Max	CV
					L Bound	U Bound			
Females	2,648								
2	37	61.5*	3.0	0.5	60	62	54	68	4.9
3	54	64.8***	3.3	0.5	64	66	58	72	5.1
4	62	66.4***	3.2	0.4	66	67	60	75	4.8
5	99	68.7***	4.1	0.4	68	70	56	82	6.0
6	115	71.3***	4.2	0.4	70	72	61	81	5.9
7	177	74.4***	4.3	0.3	74	75	64	87	5.8
8	143	75.4***	4.0	0.3	75	76	66	88	5.4
9	179	78.4***	4.3	0.3	78	79	70	90	5.5
10	161	80.8***	4.4	0.3	80	82	67	93	5.5
11	208	83.4***	4.3	0.3	83	84	71	95	5.2
12	181	83.9***	4.7	0.3	83	85	71	96	5.6
13	189	84.4***	4.5	0.3	84	85	73	96	5.3
14	209	85.5***	4.0	0.3	85	86	76	95	4.6
15	259	85.8***	4.0	0.3	85	86	77	97	4.7
16	227	85.5***	3.9	0.3	85	86	75	97	4.5
17	183	84.9***	3.6	0.3	84	85	74	95	4.3
18	165	85.4***	4.0	0.3	85	86	75	96	4.7
Males	2,612								
2	33	63.6	3.7	0.6	62	65	56	72	5.8
3	61	67.0	3.7	0.5	66	68	59	81	5.4
4	91	69.6	3.1	0.3	69	70	63	78	4.4
5	119	72.9	3.7	0.3	72	74	65	84	5.1
6	112	74.5	4.1	0.4	74	75	65	88	5.5
7	191	77.5	4.4	0.3	77	78	65	91	5.7
8	152	79.2	4.1	0.3	79	80	71	93	5.2
9	179	82.2	4.5	0.3	82	83	70	95	5.4
10	182	83.8	4.4	0.3	83	84	73	98	5.3
11	225	87.3	4.9	0.3	87	88	75	103	5.6
12	213	90.2	5.3	0.4	89	91	78	106	5.9
13	217	92.1	4.7	0.3	91	93	81	106	5.1
14	225	93.8	4.6	0.3	93	94	82	105	5.0
15	198	95.1	4.4	0.3	94	96	86	107	4.7
16	145	96.3	4.3	0.4	96	97	85	108	4.5
17	155	95.3	4.7	0.4	95	96	87	108	4.9
18	114	96.1	4.9	0.5	95	97	84	108	5.1

Significant difference between males and females obtained using ANOVA: * $p<0.05$; ** $p<0.005$; *** $p<0.001$

Discussion

The objective of this study was to examine the gender-specific growth patterns of transversal truncal and extremities' dimensions from early childhood to adulthood. Contrary to the longitudinal dimensions of the body in which only slight gender differences have been observed in pre-pubertal age[1,14–17], the current results document a pronounced sexual dimorphism in transversal dimensions from early childhood on. With the exception of biacromial and biiliocristal diameters, this trend is noticeable in all remaining measured widths: antero-posterior and transversal chest diameters, and bicondylar humerus and femur diameters. All were significantly larger in boys. The results correspond to those obtained by Humphrey[18] who emphasized that gender differences occur in many parts of the skeleton prior to adolescence. The finding was confirmed by many other authors[19–21]. Negligible gender differences in biacromial and biiliocristal diameters observed in this study are in agreement with the findings from the Zürich longitudinal study[22] and the Hungarian National Study[15].

Increasingly wider elbows and knees in boys from early childhood to adulthood were previously documented by Prader et al.[14] in Swiss samples. Gasser et al.[19] extended these findings with the observation that growth velocity in both humerus and femur widths was slightly higher for boys from early infancy till pubertal spurt. Furthermore, Gasser et al.[19,23] stressed that legs show, independently of sex, a large prepubertal velocity and poor pubertal spurt, while biacromial width shows a significant gain during pubertal spurt. In line with this finding, Bass et al.[24] documented a more rapid growth in the legs than in the spine during pre-puberty, in contrast to the pubertal period when growth of legs slowed down while spine growth accelerated. Our results also indicated that pubertal spurt peaks appeared earlier in the extremities' diameters (knee particularly) than in the truncal diameters (biiliocristal particularly). Prader et al.[14] reported similar findings and considered them logical »since these joints have to provide strength for the massive gain in weight during the pubertal spurt and for the increase in muscle power«. Moreover, the growth patterns in our study were characterized by earlier pubertal spurt and peak velocity for femur than for humerus diameter in both genders. Smith and Buschang[25] obtained similar findings of longitudinal bone growth that indicated earlier ages at peak velocities for leg than for arm bones in both sexes. This seems logical from the point of view of the mechanostat theory which postulated that »...developmental changes in bone strength are secondary to the increasing loads imposed by larger muscle force«[26]. Evidence from the current study that point to larger extremities' diameters in males throughout the growth period, also agrees with this theory. It was shown elsewhere that the boys had a continuously larger muscle mass and bone mineral content of the extremities than the girls[27–29].

Throughout the growth period, different transversal dimensions of the body showed characteristic patterns of sexual dimorphism in the studied Croatian population. In Figure 5, the patterns for shoulder, pelvis, elbow and knee widths have been compared to those reported for Swiss[14,] Hungarian[30] and Dutch[31] populations. Although the presented curves are based on the data that were collected over a large time span, the gender differences are very similar in those four populations. Interestingly enough, similar patterns of gender differences were found in some other older studies, e.g. The Old Harvard Growth Study undertaken from 1923 to 1935.

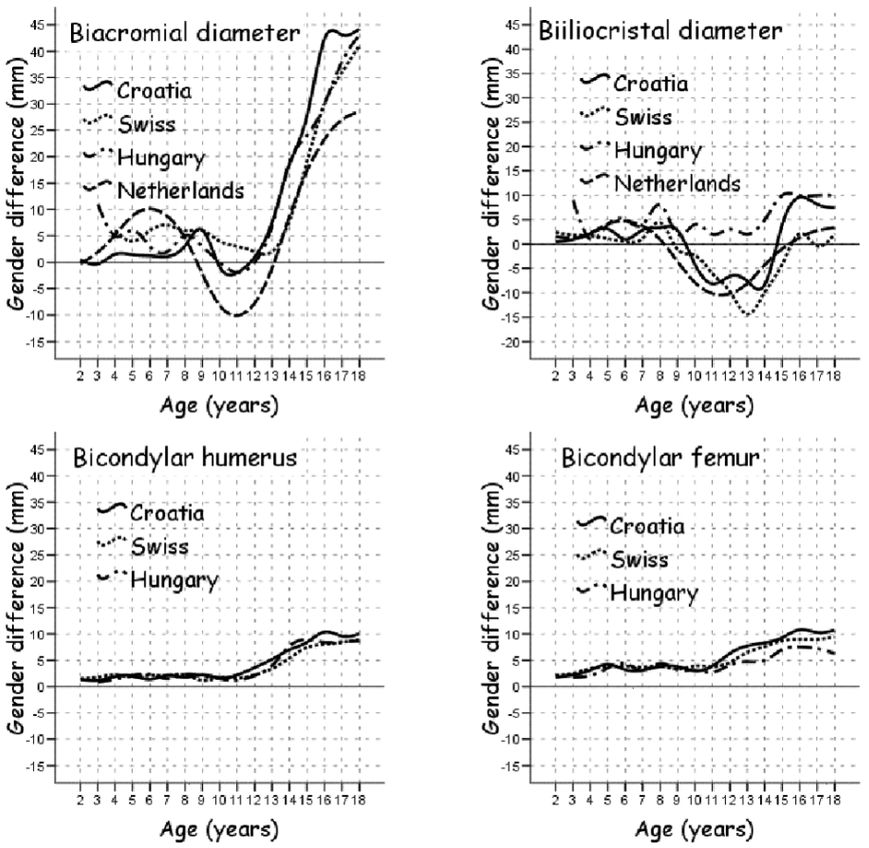

Fig. 5. Gender differences $(\overline{X}_{male} - \overline{X}_{female})$ *in biacromial, biiliocristal, bicondylar humerus and femur diameters for Croatian children compared with Swiss[14], Hungarian[30] and Dutch[31] children.*

As it was previously reported for longitudinal dimensions of the Croatian children[1], the current findings of their transversal body dimensions show that the girls attain larger amounts of their final, adult size earlier than the boys. This indicates their earlier bone maturation and agrees with the studies in other populations [19,33]. Thus, the present findings document different growth dynamics in transversal body segments during childhood and adolescence, which is gender-specific. While sexual dimorphism in shoulder and pelvis diameters emerge with pubertal spurt, gender differences in chest and extremities' diameters start early in life. Different timing and intensity of change in transversal body dimensions reflect differential functional requirements for skeletal stability and muscular strength between the sexes. This kind of data has recently gained increased attention due to its wide spectrum of possible applications in the clinical domain. The present study is a contribution in this direction.

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SPOLNO-SPECIFIČNI OBRASCI RASTA TRANSVERZALNIH DIMENZIJA TIJELA DJECE I MLADEŽI U HRVATSKOJ (2–18 GODINA STAROSTI)

S A Ž E T A K

U sklopu transverzalnog istraživanja rasta i razvoja djece i mladeži ispitano je 5260 predškolske i školske djece i mladeži grada Zagreba u dobi od 2 do 18 godina. Analizirano je šest transverzalnih dimenzija tijela i to: širina i dubina prsnog koša, širina ramena i zdjelice te širina lakta i koljena. Studija je pokazala da se sve transverzalne dimenzije tijela povećavaju do 14. i 15. godine kod djevojčica te do 16. godine kod dječaka što potvrđuje da djevojčice godinu do dvije ranije završavaju s rastom u širinu. U usporedbi s dječacima iste dobi, djevojčice tijekom cijelog razdoblja rasta dosižu viši postotak završne veličine proučavanih transverzalnih dimenzija tijela. Tako na primjer širina koljena kod djevojčica dosiže 95% završne veličine već u dobi od 10 godina. Širine pojedinih dijelova tijela pokazuju različite obrasce rasta koji se razlikuju među spolovima. Dok se spolni dimorfizam u širini zdjelice i ramena pojavljuje u vrijeme puberteta, razlike u širinama prsnog koša, lakta i koljena postoje već u ranoj dobi. Dječaci u cijelom razdoblju od 2. do 18. godine imaju širi prsni koš, lakat i koljeno. U pubertetskom razdoblju, značajno im se više povećava širina ramena (od 13. godine) dok se djevojčicama brže povećava širina zdjelice pa u toj dimenziji zadržavaju prednost pred dječacima od 10. do 14. godine. Spolni dimorfizam u transverzalnim dimenzijama tijela djece i mladeži u Hrvatskoj uspoređen je s obrascima rasta i razvoja u drugim europskim populacijama.