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THE BODY MASS AND HEIGHT VELOCITY FROM BIRTH TO THE AGE OF 6 YEARS

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Abstract: *The longitudinal investigation of children's growth as a part of the "Health and demographic survey of pregnant women and infants" is in progress. The authors have produced the longitudinally based height and body mass yearly velocity reference means and percentiles for about 5000 children from birth till the age of 6 years. Moreover, in the age of 0—2 years the growth between succeeding examinations are recalculated to yearly velocity.*

The yearly body mass and height velocities of boys and girls are studied. In the first year of age the velocity of body mass and height is significantly higher for boys (body mass: 6.68 kg/year; height: 25.53 cm/year) than girls (body mass: 6.21 kg/year; height: 24.75 cm/year). In the second, third and fourth years of age the body mass and height velocities of girls is greater than that of boys, however, the ever decreasing difference becomes significant only during the second and third years of age.

In the first three months following the birth the yearly body mass velocity values calculated for one year are 9.31; 11.52 and 10.38 kg/year for boys and 8.41; 9.96 and 9.29 kg/year for girls, respectively. The body height (length) development values are 39.51; 40.81 and 39.73 cm/year for boys, and 38.51; 37.73 and 36.91 cm/year for girls.

Key words: *Hungarian longitudinal study on a national representative sample; Body mass velocity; Height velocity.*

Introduction

The child's intensity of growth (velocity) of various body measures characteristic of the life period referred can be estimated only by means of a longitudinal study. The first follow up study was carried out by count Philiber Gueneau de Montbeillard with his own child from 1759 through 1777 (Scammon 1927). This was the first accurate information also on the yearly velocity of the child's body height. Investigations on the body mass and height velocity of children carried out with scientific exaction may be reckoned from the publication of Robertson, T.B. published in 1915. In course of time the importance of knowledge on the velocity characteristic of each ages has grown more and more. This perception greatly contributed to the spread of longitudinal investigations. Without any demand on completeness some longitudinal studies will be mentioned as follows: Tanner et al. (1966, 1985), Karlberg & Taranger (1976), Prader & Budliger (1977), Brandt (1980), Eiben et al. (1982), Gács et al. (1988), and finally the research programme carried out by us: Joubert & Ágfalvi (1989), Joubert & Gárdos (1991).

Material and method

The longitudinal children's growth study as a part of the research programme entitled "Health and demographic survey of pregnant women and infants" started in the year 1980 has been going on at present, too. The research realized on a 2 percent representative national sample has been carried out in co-operation by the Demographic Research Institute of the Hungarian Central Statistical Office and the National Institute of Child Health with the assistance of district nurses.

From among the total of children investigated a so called reference group was formed including newborn babies born with a body mass of 2500–4500 gs who had not suffered

from any illness influencing growth, development or any other chronic disease. This reference group included 2993 boys and 2688 girls at birth, and 2470 boys and 2198 girls at the age of 6 years.

In the calculations of velocity only the data of children were taken into account who where measured at the date of both the start and the ending. Accordingly the case numbers belonging to the velocity values of the periods are smaller than the numbers of children included at the start and end (See *Tables 1* and *4*).

Findings, Evaluation

Body mass velocity

Reference values of the body mass means at birth of children investigated are as follows: boys 3313 g (SD = 417.4 g); girls 3202 g (SD = 392.7 g) (Joubert & Ágfalvi 1988). Examining the difference between the body mass means of boys and girls at birth using *t*-test we got a rather highly significant value (Joubert & Ágfalvi 1989).

Table 1. **Reference means and percentiles of the yearly body mass velocity from birth to the age of six years**

Period (year)	N	Mean kg/year	SD	SE	V_{min}	V_{max}	Percentiles						
							3	10	25	50	75	90	97
Boys													
0—1	2762	6.68	0.99	0.02	3.68	10.70	4.97	5.47	6.00	6.62	7.30	7.99	8.69
1—2	2590	2.64	0.83	0.02	0.15	8.70	1.20	1.70	2.10	2.55	3.10	3.65	4.34
2—3	2168	2.23	1.05	0.02	0.10	12.00	0.50	1.00	1.50	2.10	2.80	3.50	4.50
3—4	2328	1.91	1.44	0.03	0.10	50.70	0.50	0.70	1.20	1.80	2.50	3.10	4.00
4—5	2378	2.15	1.22	0.03	0.10	11.70	0.50	0.90	1.40	2.00	2.60	3.50	5.00
5—6	2455	2.47	1.42	0.03	0.10	12.00	0.50	1.00	1.50	2.20	3.00	4.00	6.00
Girls													
0—1	2515	6.21	0.97	0.02	3.25	11.85	4.56	5.05	5.55	6.15	6.80	7.45	8.27
1—2	2349	2.72	0.87	0.02	0.20	13.00	1.40	1.78	2.20	2.65	3.15	3.80	4.58
2—3	2057	2.29	1.02	0.02	0.10	10.00	0.70	1.10	1.60	2.20	2.90	3.50	4.61
3—4	2194	1.96	1.07	0.02	0.10	8.00	0.50	0.80	1.20	1.80	2.50	3.30	4.30
4—5	2260	2.16	1.24	0.03	0.10	9.30	0.50	0.90	1.30	2.00	2.80	3.70	5.10
5—6	2367	2.44	1.39	0.03	0.10	13.20	0.50	1.00	1.50	2.20	3.00	4.00	5.70

Reference means and reference percentiles of the yearly body mass velocity of boys and girls are presented in *Table 1*. During the first year of life the body mass velocity of boys is highly significantly greater than that of girls ($t = 17.158$, $p < 0.001$). Moreover, the difference between the body mass of the two sexes at birth further increases. During the second year of life, however, the body mass velocity of girls becomes strongly significantly higher than that of boys ($t = 3.637$, $p < 0.01$). In the course of the third year again the body mass increase of girls is more intensive, nevertheless, the difference between the means may be qualified only as significant ($t = 2.159$, $p < 0.05$). In the course of the fourth and fifth year the surplus of girls' body mass velocity decreases so much (during the fifth year being only 0.01 kg/year) that the difference between the means is already not significant. In the sixth year the body mass velocity of boys is more intensive again, although the difference here, does not reach the level of statistical significance.

Reference percentiles of body mass velocity per year can be seen on *Figures 1*. One can observe on the figures that the difference between the two extremes (perecentiles 3th and 97th) somewhat decreases under the second year, for both boys and girls. In the following years, however, the distance between the lower and upper extremes of the percentiles increases more or less uniformly. If we look at the extremes relating to the percentile 50th (similarly to the cases of percentiles 10th, 25th and 75th) as well as 90 th we can see that the upper "channels" are at each age broader than the lower ones. At the age of six years 50 per cent of the children shows a body mass velocity higher than 2.20 kg/year, while the other half of them produces less than that value. At this age the mass velocity of 3 per cent of the children is 0.50 kg/year or less in both sexes; they represent the group of children with the slowest mass growth. 3 per cent of the boys shows a mass

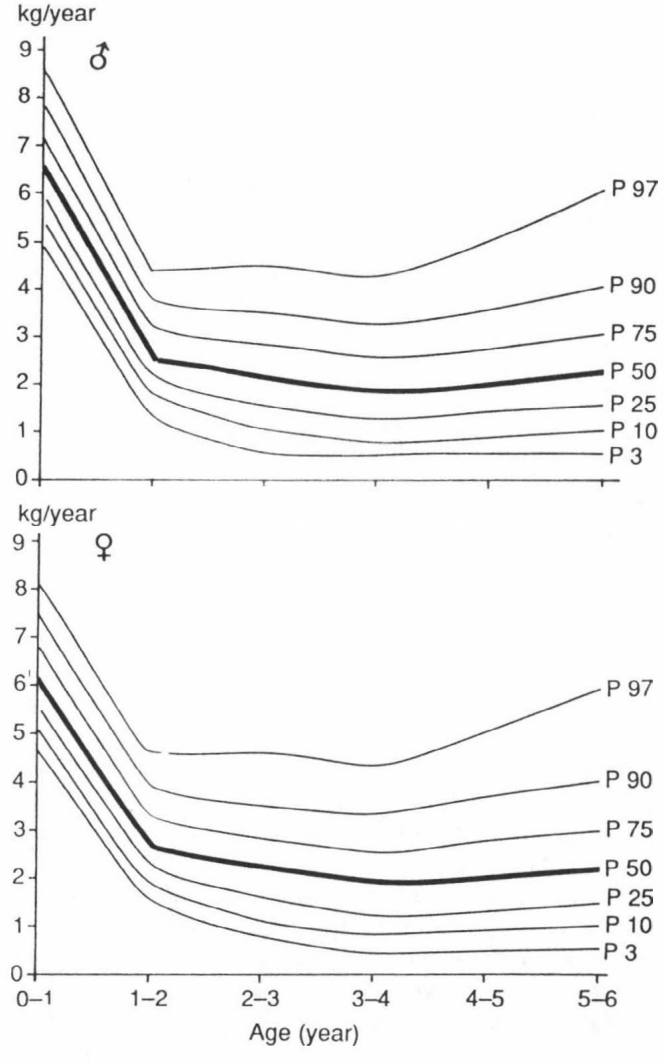

Fig. 1: Reference percentiles of the yearly body mass velocity, boys and girls

Table 2. **Reference means and percentiles of body mass velocity calculated for one year by periods of the investigation**

Period studied (month)	N	Mean kg/year	SD	SE	V_{min}	V_{max}	Percentiles						
							3	10	25	50	75	90	97
Boys													
0— 1	2897	9.31	3.82	0.07	0.48	30.00	2.76	4.68	6.61	9.01	11.77	14.34	17.39
1— 2	2938	11.52	3.89	0.07	0.12	30.72	4.57	6.61	9.00	11.39	13.93	16.80	19.22
2— 3	2934	10.38	3.78	0.07	1.20	29.40	4.20	6.00	7.80	10.19	12.60	15.13	18.60
3— 4	2909	8.97	3.50	0.06	0.06	35.16	3.36	4.81	6.61	8.65	10.81	13.21	16.80
4— 5	2867	7.61	3.21	0.06	0.12	40.21	2.40	3.84	5.41	7.20	9.60	11.88	14.41
5— 6	2822	6.58	3.13	0.06	0.12	30.48	1.68	3.00	4.44	6.12	8.40	10.57	13.21
6— 8	2787	4.90	2.09	0.04	0.12	19.20	1.44	2.40	3.60	4.80	6.01	7.80	9.06
8—10	2742	4.33	1.99	0.04	0.18	16.20	1.14	1.98	3.00	4.20	5.41	6.90	8.42
10—12	2731	4.04	2.08	0.04	0.12	27.90	0.84	1.80	2.70	3.84	5.10	6.60	8.45
12—15	2552	3.03	1.62	0.03	0.04	12.80	0.60	1.20	2.00	2.80	4.00	5.20	6.40
15—18	2455	2.83	1.70	0.03	0.40	22.00	0.40	1.20	1.60	2.40	3.60	4.80	6.41
18—21	2388	2.69	1.57	0.03	0.40	16.00	0.40	1.20	1.60	2.40	3.60	4.41	6.40
21—24	2315	2.80	1.82	0.04	0.40	16.00	0.40	0.80	1.60	2.40	3.60	5.20	6.01
24—36	2268	2.23	1.05	0.02	0.10	12.00	0.50	1.00	1.50	2.10	2.80	3.50	4.50
36—48	2328	1.91	1.44	0.03	0.10	50.70	0.50	0.70	1.20	1.80	2.50	3.10	4.00
48—60	2378	2.15	1.22	0.03	0.10	11.70	0.50	0.90	1.40	2.00	2.60	3.50	5.00
60—72	2455	2.47	1.42	0.03	0.10	12.00	0.50	1.00	1.50	2.20	3.00	4.00	6.00
Girls													
0— 1	2659	8.41	3.43	0.07	0.06	21.96	2.40	4.20	6.01	8.27	10.56	12.97	15.60
1— 2	2687	9.96	3.31	0.06	0.60	24.60	4.20	6.00	7.80	9.61	12.01	14.40	16.81
2— 3	2666	9.29	3.45	0.07	0.54	31.20	3.60	5.40	6.85	9.00	11.39	13.79	16.21
3— 4	2651	8.37	3.20	0.06	0.60	30.60	3.00	4.80	6.06	8.16	10.20	12.59	15.24
4— 5	2609	7.07	2.95	0.06	0.24	24.00	2.40	3.60	5.04	6.73	8.76	10.81	13.21
5— 6	2582	6.18	2.87	0.06	0.12	26.40	1.80	3.00	4.21	6.00	7.80	9.61	12.02
6— 8	2559	4.75	1.98	0.04	0.06	15.90	1.38	2.40	3.48	4.50	6.00	7.21	9.00
8—10	2504	4.21	1.90	0.04	0.06	15.00	1.20	1.92	3.00	4.08	5.40	6.60	8.29
10—12	2475	3.98	2.01	0.04	0.06	21.60	0.90	1.80	2.70	3.66	4.81	6.30	8.58
12—15	2552	3.03	1.62	0.03	0.04	12.80	0.60	1.20	2.00	2.80	4.00	5.20	6.40
15—18	2211	2.95	1.66	0.04	0.40	15.20	0.40	1.20	2.00	2.80	4.00	5.20	6.41
18—21	2179	2.71	1.63	0.03	0.40	17.60	0.40	0.80	1.60	2.40	3.60	4.80	6.40
21—24	2145	2.85	1.87	0.04	0.40	20.00	0.40	0.80	1.60	2.40	3.60	5.20	6.40
24—36	2057	2.29	1.02	0.02	0.10	10.00	0.70	1.10	1.60	2.20	2.90	3.50	4.61
36—48	2194	1.96	1.07	0.02	0.10	8.00	0.50	0.80	1.20	1.80	2.50	3.30	4.30
48—60	2260	2.16	1.24	0.03	0.10	9.30	0.50	0.90	1.30	2.00	2.80	3.70	5.10
60—72	2367	2.44	1.39	0.03	0.10	13.20	0.50	1.00	1.50	2.20	3.00	4.00	5.70

increase of 6.00 kg/year or more, while 3 per cent of the girls shows 5.70 kg/year or more forming the group of the most intensively thriving children in the reference group.

The investigation of the yearly values of body mass velocity does not allow us to realize the velocity situation during the most intensive thriving period: infancy. Therefore we elaborated the method of transformation of the growth velocity values found at the investigation periods to yearly values. (For the purpose of comparability among investigation periods of various length it is necessary to transform the velocities to a uniform period, in this case to years.)

The reference values (transformed to years) of the body mass velocity means and percentiles determined for the investigation periods are presented in *Table 2* for boys and girls. One can observe well also in the table how significant difference is between

the body mass growth intensities of the first and second halves within the first year of life. And even within the first half-year the second and third months have proved to be the most intensive thriving periods. Also the fact deserves attention that the difference is the largest in the first few months – obviously – also between the body mass mean velocities of boys and girls. In that period, namely during the second and third months, the body mass velocity is 11.52 and 10.38 kg/year, respectively, for boys, while 9.96 and 9.29 kg/year, respectively, for girls. Investigating the body mass mean velocities of boys and girls by *t*-test the following conclusions may be drawn.

The mean velocity of boys' body mass growth from birth through the end of the first month of age is highly significantly larger than that of girls ($t = 9.369$, $p < 0.001$). The mean velocity of body mass increase reaches the top value at the age of 2 months for both boys and girls. The mean velocity of boys' body mass increase is 1.56 kg/year larger than that of girls; this difference, naturally, may be regarded as statistically very significant ($t = 16.392$, $p < 0.001$). Following that period, the mean body mass velocity strongly decreases month by month, on the one hand, and the surplus body mass velocity of boys comparing to that of girls becomes more and more moderate, on the other hand. The size of the difference between the means of the velocities of boys and girls decreasing month by month proves to be very strongly significant during the first six month (in the third month $t = 12.136$, in the fourth month $t = 6.635$, in the fifth month $t = 5.862$, in the sixth month $t = 4.039$, $p < 0.001$). After that during the seventh–eighth months the difference between the means is already only strongly significant ($t = 3.329$, $p < 0.01$). However, during the 9–10th and 11–12th months the body mass velocity of boys is so little more than that of girls that the difference is not significant statistically. During the first quarter of the second year of age (in the 13–15th months) boys and girls produce almost the same velocity. During the following three quarters of the second year already the mean body mass velocity of girls is higher than that of boys. The difference between the means reaches the statistically significant value only in the months 16 and 18 ($t = 2.156$, $p < 0.05$). The differences between the means of velocities during the further, yearly investigation periods have been mentioned already above.

Reference percentiles of the body mass velocity by periods of the investigation computed for one year are presented on *Figures 2*, from birth till the age of 6 years. One can see clearly on the figures that the differences between the extreme percentile values (as velocity values are transformed to years) are rather significant especially at the early infancy. For instance, in the first three months the deviations of the growth velocity between percentiles 3 and 97 are 14.63, 14.65 and 14.40 kg/year for boys, and 13.20, 12.61 and 12.61 kg/year for girls. This means that within such a broad domain the growth velocity values calculated to one year may be regarded still as physiological. Within this broad domain the channel limited above by the 3rd percentiles and limited below by the 10th percentiles, on the one hand, and the channel whose lower limit is the curve of the 90th percentiles and the upper limit is the one of 97th percentiles, on the other, correspond to the category is "still appropriate" to his/her age (or to that aspect according to which the percentile had been calculated), according to the international practice; the domains between 10 and 25; 75 and 90 resp. are "appropriate"; the field between percentiles 25 and 75 means a "rightly appropriate" qualification.

Nevertheless, it is not sufficient to take only the velocity of the period in question calculated for one year as the basis of judging whether the growth is satisfactory or pathological, but attention should be paid to the tendency of the development of the velocity

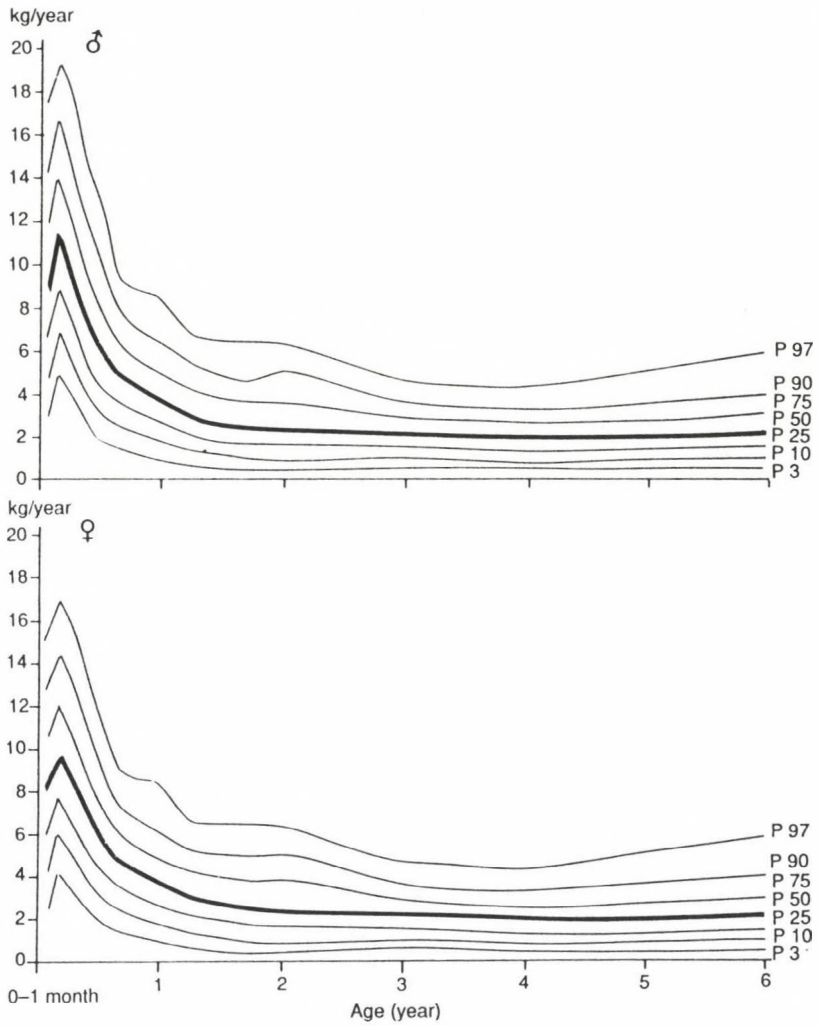

Fig. 2: Reference percentiles of the body mass velocity calculated for one year by periods of the investigation to the age of six years, boys and girls

based on the velocity values of earlier periods. Comparing the velocity trend of the child investigated to reference values of the same period one can truly judge whether the growth is appropriate or pathological.

The publication of the reference means and reference percentiles of the growth velocity is deemed necessary in order to use them by practicing paediatrists and nurses as an "etalon" offering the possibility for comparing the growth velocity of children investigated and measured continuously and thus to perceive any possible pathological deviation in due time and to cease its cause (Gács et al. 1988).

The development of the body mass velocities of children investigated have been analysed not only by successive periods but also for larger intervals. In all cases birth was taken as starting point, and reference means and reference percentiles of body mass

Table 3. **Reference values of body mass velocity from birth**

Period studied (months completed)	N	Mean of body mass velocity (kg)	SD	Percentiles						
				3	10	25	50	75	90	97
Boys										
birth — 1	2803	0.78	0.32	0.24	0.39	0.55	0.75	0.98	1.20	1.45
birth — 3	2782	2.61	0.54	1.60	1.93	2.25	2.60	2.95	3.30	3.65
birth — 6	2698	4.52	0.74	3.20	3.60	4.00	4.49	5.00	5.50	6.00
birth — 12	2664	6.69	0.99	5.00	5.48	6.00	6.62	7.30	8.00	8.74
birth — 18	2464	8.08	1.16	6.10	6.70	7.30	8.00	8.80	9.56	10.41
birth — 24	2453	9.34	1.34	7.10	7.74	8.43	9.22	10.14	11.05	12.06
birth — 36	2240	11.50	1.77	8.74	9.49	10.35	11.31	12.45	13.70	15.21
birth — 48	2281	13.36	2.10	10.11	11.05	12.00	13.14	14.46	15.86	17.85
birth — 60	2333	15.49	2.63	11.60	12.70	13.76	15.12	16.77	18.55	21.25
birth — 72	2350	17.94	3.37	13.20	14.50	15.79	17.38	19.40	21.82	25.50
Girls										
birth — 1	2518	0.70	0.29	0.20	0.35	0.50	0.68	0.87	1.08	1.28
birth — 3	2481	2.30	0.49	1.44	1.69	1.96	2.27	2.60	2.95	3.25
birth — 6	2411	4.09	0.69	2.90	3.23	3.60	4.05	4.54	5.00	5.51
birth — 12	2361	6.22	0.95	4.61	5.07	5.56	6.15	6.79	7.43	8.18
birth — 18	2164	7.65	1.15	5.75	6.28	6.90	7.55	8.34	9.11	10.10
birth — 24	2183	8.95	1.35	6.70	7.40	8.05	8.86	9.71	11.69	11.60
birth — 36	1981	11.16	1.78	8.20	9.10	10.00	11.01	12.16	13.38	14.79
birth — 48	2015	13.10	2.14	9.65	10.81	11.71	12.91	14.21	15.62	17.48
birth — 60	2084	15.23	2.79	11.30	12.29	13.45	14.91	16.55	18.45	21.00
birth — 72	2087	17.65	3.43	12.81	14.01	15.41	17.14	19.26	21.71	25.19

Table 4. **Reference means and percentiles of the yearly body height velocity from birth to the age of six years**

Period (year)	N	Mean cm/year	SD	SE	V_{min}	V_{max}	Percentiles						
							3	10	25	50	75	90	97
Boys													
0—1	2759	25.53	2.79	0.05	13.60	41.90	20.02	22.02	23.82	25.60	27.33	28.85	30.73
1—2	2590	11.68	2.56	0.05	1.00	27.00	6.51	8.60	10.30	11.80	13.02	14.52	16.51
2—3	2317	8.41	3.06	0.06	0.10	27.20	3.20	5.10	6.50	8.01	10.00	12.01	15.02
3—4	2379	6.63	2.43	0.05	0.10	18.40	2.00	3.50	5.11	6.61	8.01	9.51	11.81
4—5	2424	6.70	2.65	0.05	0.20	68.80	2.00	3.90	5.50	6.70	7.81	9.11	11.41
5—6	2497	6.53	2.29	0.05	0.10	29.20	2.30	4.00	5.30	6.50	7.51	8.91	11.10
Girls													
0—1	2513	24.75	2.79	0.06	8.70	36.30	19.42	21.32	23.01	24.81	26.43	28.15	29.94
1—2	2345	12.11	2.61	0.05	2.00	27.20	7.00	9.01	10.71	12.01	13.52	15.02	17.00
2—3	2082	8.68	3.10	0.07	0.20	24.10	3.31	5.11	6.71	8.31	10.21	12.71	15.31
3—4	2234	6.72	2.56	0.05	0.10	22.20	1.60	3.50	5.21	6.81	8.11	9.41	11.81
4—5	2312	6.78	2.23	0.05	0.30	19.70	2.50	4.00	5.51	6.81	8.01	9.21	11.21
5—6	2417	6.56	2.27	0.05	0.40	37.50	2.60	4.10	5.31	6.50	7.60	8.81	11.01

increase were calculated from birth to the various ages (*Table 3*). Comparing the body mass velocity values of boys and of girls (*Table 3*) from birth one can see that boys' growth velocities are larger in all life periods up to the age of six years. Nevertheless, as shown also by the data of Table 1, the means of growth velocity of girls were somewhat higher even during the ages of the second, third, fourth and fifth years, still their

summarized values have not compensated the surplus of body mass velocity of boys gained during the first year either. According to the data of *Table 4* the children's growth velocity during the first year is more than the double of the body mass at birth. By the end of the second year of age the body mass growth approaches the treble of the body mass at birth, while the growth by the end of the sixth year amounts to nearly 5.5-fold of the value at birth.

Body length/body height velocity

Reference values of the body length means of children investigated are as follows: for boys 50.81 cm (SD = 2.19 cm), for girls 50.14 cm (SD = 2.07 cm) (Joubert & Ágfalvi 1988). Studying the difference between the body height of boys' and girls' means at birth by *t*-test we have got highly significantly great differences (Joubert & Ágfalvi 1989).

Table 5. **Reference means and percentiles of body height (length) velocity calculated for one year by periods of the investigation**

Period studied (month)	N	Mean cm/year	SD	SE	V_{min}	V_{max}	Percentiles						
							3	10	25	50	75	90	97
Boys													
0— 1	2879	39.51	17.84	0.33	1.20	184.80	8.41	16.82	27.60	38.43	50.42	61.28	74.44
1— 2	2931	40.81	16.85	0.31	1.20	122.40	12.01	19.21	30.00	39.65	50.43	61.24	73.23
2— 3	2932	39.73	16.42	0.30	2.40	156.00	12.01	19.22	28.82	37.24	48.05	60.07	72.08
3— 4	2891	33.65	15.21	0.28	1.20	126.00	8.40	14.42	24.01	32.43	42.04	54.02	66.01
4— 5	2860	30.25	14.76	0.28	1.20	144.00	7.20	12.01	21.60	28.83	37.23	48.03	60.05
5— 6	2811	26.16	13.73	0.26	1.20	144.00	6.00	10.81	16.81	24.02	34.83	43.23	54.05
6— 8	2783	17.23	7.75	0.15	0.60	49.20	3.61	7.20	12.00	17.41	22.22	27.04	33.00
8—10	2750	15.85	7.49	0.14	0.60	54.00	3.00	6.00	10.81	15.02	21.00	25.21	31.23
10—12	2744	16.23	8.10	0.15	0.60	77.40	3.00	6.00	10.81	15.02	21.01	27.02	33.04
12—15	2620	13.16	6.45	0.13	0.40	60.40	2.40	5.20	8.01	12.01	16.81	20.81	26.00
15—18	2525	11.77	5.96	0.12	0.40	66.00	2.40	4.01	8.00	12.00	15.62	20.00	24.02
18—21	2505	11.08	5.74	0.11	0.40	41.20	2.00	4.00	7.60	10.80	14.42	18.02	23.62
21—24	2479	11.30	6.69	0.13	0.40	66.40	2.00	4.00	6.81	10.41	14.80	20.00	24.01
24—36	2317	8.41	3.06	0.06	0.10	27.20	3.20	5.10	6.50	8.01	10.00	12.01	15.02
36—48	2379	6.63	2.43	0.05	0.10	18.40	2.00	3.50	5.11	6.61	8.01	9.51	11.81
48—60	2424	6.70	2.65	0.05	0.20	68.80	2.00	3.90	5.50	6.70	7.81	9.11	11.41
60—72	2497	6.53	2.29	0.05	0.10	29.20	2.30	4.00	5.30	6.50	7.51	8.91	11.10
Girls													
0— 1	2638	38.51	17.67	0.34	1.20	159.60	6.01	16.80	26.40	37.24	49.25	60.10	72.08
1— 2	2680	37.73	15.89	0.31	1.20	150.00	12.00	18.01	25.52	36.04	48.02	58.86	69.69
2— 3	2659	36.91	15.82	0.31	1.20	120.00	10.81	18.01	25.21	36.03	48.00	57.62	72.01
3— 4	2638	32.38	14.88	0.29	1.20	106.80	8.41	13.21	24.00	30.04	40.85	50.44	64.83
4— 5	2606	28.91	14.10	0.28	1.20	168.00	6.00	12.01	19.20	27.61	36.04	48.00	58.90
5— 6	2543	25.42	13.71	0.27	1.20	122.40	6.00	9.61	15.60	24.01	33.62	43.20	54.02
6— 8	2547	17.30	7.98	0.16	0.60	84.00	3.61	7.80	12.00	16.82	22.22	27.03	34.23
8—10	2500	15.90	7.51	0.15	0.60	57.00	3.00	6.01	10.81	15.02	20.42	25.21	31.22
10—12	2491	16.71	8.31	0.17	0.60	77.40	3.00	6.00	11.41	16.20	21.60	27.03	33.05
12—15	2353	13.36	6.29	0.13	0.40	60.00	3.60	6.00	8.40	12.80	17.21	21.20	25.22
15—18	2279	12.40	6.15	0.13	0.40	54.00	2.00	4.40	8.01	12.01	16.01	20.02	24.81
18—21	2271	11.63	5.98	0.13	0.40	56.00	2.00	4.01	8.00	11.60	15.20	19.21	24.02
21—24	2271	11.59	7.02	0.15	0.40	71.20	2.00	4.00	7.21	10.41	15.20	20.00	24.01
24—36	2082	8.68	3.10	0.07	0.20	24.10	3.31	5.11	6.71	8.31	10.21	12.71	15.31
36—48	2234	6.72	2.56	0.05	0.10	22.20	1.60	3.50	5.21	6.81	8.11	9.41	11.81
48—60	2312	6.78	2.23	0.05	0.30	19.70	2.50	4.00	5.51	6.81	8.01	9.21	11.21
60—72	2417	6.56	2.27	0.05	0.40	37.50	2.60	4.10	5.31	6.50	7.60	8.81	11.01

Reference means and reference percentiles of the body height (length) growth velocities by years are presented in *Table 5* for boys and girls. Studying the yearly development of the velocity means, one can see that their values are the highest in the course of the first year of age. During this period, namely, the body length at birth of the children increases nearly by its half. During the second year of age the growth does not reach one quarter of the body length at birth either. The body height velocity during the third year of age is about 17 per cent of the length at birth, later in the course of the fourth, fifth at sixth years about 13 per cent.

Analysing the differences between the growth velocities of boys, resp. girls by *t*-test one can see as follows:

During the first year of age the body height velocity is 0.78 cm/year larger than that of girls, this difference proved to be statistically very strongly significant ($t = 10.988$, $p < 0.001$). In the following years, to the age of six years, the body height velocity of girls is larger than that of boys. During the second year the girls' 0.43 cm/year larger velocity may be regarded still as very strongly significant difference ($t = 5.135$, < 0.001). In the course of the third year of age the boys' body height velocity is 0.23 cm/year smaller that of girls, that is a statistically strongly significant difference ($t = 3.378$, $p < 0.01$). However, also during the fourth, fifth and sixth years of age the body height velocity of girls is more intensive than that of boys, but the deviation is not significant statistically.

Thus, summarizing it may be stated that the boys' larger body length at birth as well as the higher velocity during the first year of age proved to be satisfactory for ensuring their body height advantage over girls up to the age of six. The mean body height at six years of age is 116.33 cm for boys, and 115.62 cm for girls. Analysing the difference between the two means by *t*-test, it may be qualitied as very strongly significant ($t = 4.802$, $p < 0.001$).

Reference percentiles of the yearly velocities of body height (length) are presented on *Figures 3*. On the figures one can clearly observe that the "channels" formed by the percentiles 3 and 97 and by the percentile 50 are much less asymmetrical than those observed with body mass percentiles. Disregarding the first year of age when the lower "channel" is a little broader, during the following periods of the age percentile 97 is more or less in the same distant from the percentile 50 than the percentile 3. The lower and upper limits of percentiles get the farthest from percentile 50 – thus, also from each other – during the third year of age. Accordingly, naturally, also the value of standard deviation (SD) is the largest in this period (3.06 for boys, 3.10 for girls).

Summarizing the findings on the development of the yearly body height (length) growth percentiles one may say that the very intensive growth velocities experienced in the first year of age are followed by a very intensive decrease of the velocity during the second year, whenever the value of the growth velocity gets reduced to less than the half of the former year value. The body height (length) velocity further decreasing in the course of the third year of age turns into a nearly equalized intensity of growth during the fourth, fifth and sixth years of age. It should be mentioned here that the information got from data of single measurements, or from the situation of velocity values of a single period in the percentile "channels" must not be overestimated; for instance if a child's body height is under percentile 3 being thus lower than appropriate to his age. However, if body height does not increase with the repeated measurements, or increases very little (the value of the velocity is zero or hardly more than zero) then the pathological back-

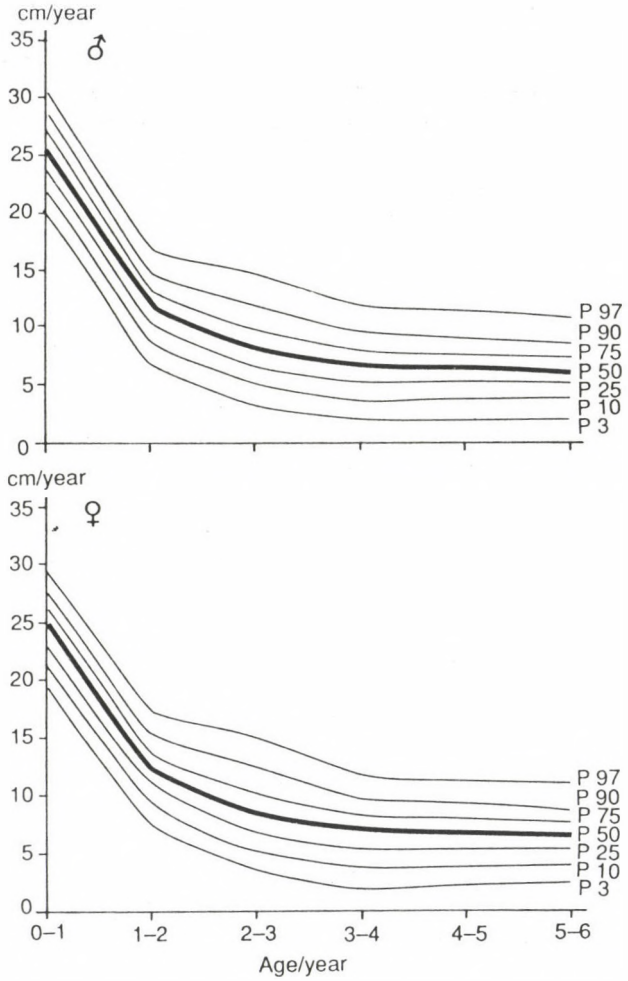

Fig. 3: Reference percentiles of the yearly body height (length) velocity, boys and girls

ground of the stop of growing must be medically checked up. If necessary, human growth hormone treatment (hGH) can start growing again (Tanner et al. 1985). That means, for the correct evaluation of the data measured and calculated (beyond the health and physical status of the child) data of earlier measurements must be taken into consideration, in lack of these the data at birth, and measurements must be repeated with adequate frequency. The necessary frequency of the repetition of measuring depends on both the type of the measure and the age of the child.

For answering the question, how does the body height velocity really develop in the course of the very intensive progress of growth observed during the first and second year of age, the presentation of the velocity values by investigation periods can give a real picture.

Reference means and reference percentiles of the body height (length) velocities found by investigation periods and calculated for one year are presented in *Table 5*. The

means in the table clearly show the partial velocities building up the 25 cm/year growth velocity of the first year of age. After the peak velocity (40.81 cm/year) observed in the second month with boys the body height velocity decreases suddenly, coming down with a run until the sixth month; with girls that happens from the first month, where their velocity is the highest: 38.51 cm/year. (It is interesting that the mean velocities observed in the sixth month (boys: 26.16 cm/year, girls: 25.42 cm/year) are nearly the same as the velocity means of the first year of age.) In the course of the second half of the year during the two-month investigation periods the velocity of growth further decreases, but more moderately, and even in the eleventh–twelfth months for both boys and girls, somewhat higher values are found than in the previous two-month period.

In the second year of age the investigations were carried out quarterly, thus the velocities were calculated for three month periods, too. The decline measured quarterly, being more and more moderate, amounts to cca. 2 cm/year. The growth velocities of yearly periods of further ages were mentioned above.

The statistical values of the differences between the reference means of boys' and girls' body height (length) velocities measured by investigation periods, calculated for one year were analysed with *t*-test. During the first month boys grow significantly more rapidly than girls ($t = 2.08969$, $p < 0.05$). In the course of the second month the boys' growth velocity further increases, while that of girls decreases. Consequently the difference between the means is very strongly significant ($t = 6.8817$, $p < 0.001$).

The more intensive growth of the boys is definite also during the further months of the half year, although the difference between the means becomes ever smaller, in the months 3, 4 and 5 it is still very strongly significant [$t\,(3) = 7.0396$, $p < 0.001$; $t\,(4) = 3.4216$, $p < 0.001$; $t\,(5) = 3.6490$, $p < 0.001$]. In the sixth month the boys' velocity mean is still larger than that of girls, but the difference is not significant statistically. After the sixth month up to six years of age of the children investigated in all periods the body height (length) velocity of girls is larger. The difference between velocity means reaches the statistically significant level only in three periods: in the course of the eleventh–twelfth months, the difference is significant there ($t = 2.2223$, $p < 0.05$); in the second quarter of the second year, where it is very strongly significant ($t = 3.67608$, $p < 0.001$), and during the months 19–21, when the difference between the means is strongly significant ($t = 2.9664$, $p < 0.01$).

Reference percentiles of growth velocity of the body height (body length) calculated for one year by periods of the investigations are illustrated from birth to age of six years in *Figures 4*. On the figures one can well observe how great differences do exist between percentiles 3 and 97 during the first two years and especially during the first half year after birth, as compared to the percentiles of the yearly growth velocity.

That means, while between the extreme percentiles of the growth velocity of the first year of age a difference of 10 cm/year is observable, between the percentiles of growth velocity calculated for one year by the end of the first month after birth a difference of nearly 70 cm/year can be seen both for boys and girls (*Figure 4*). At that time higher percentile values are somewhat farther from percentile 50 (being about 38 cm/year), as well as also at the further periods of investigation than the lower ones. As a result of the strong decrease of velocity of growth the difference the two extreme percentiles diminishes to 48 cm/year during the sixth month, and to 30 cm/year by the two last

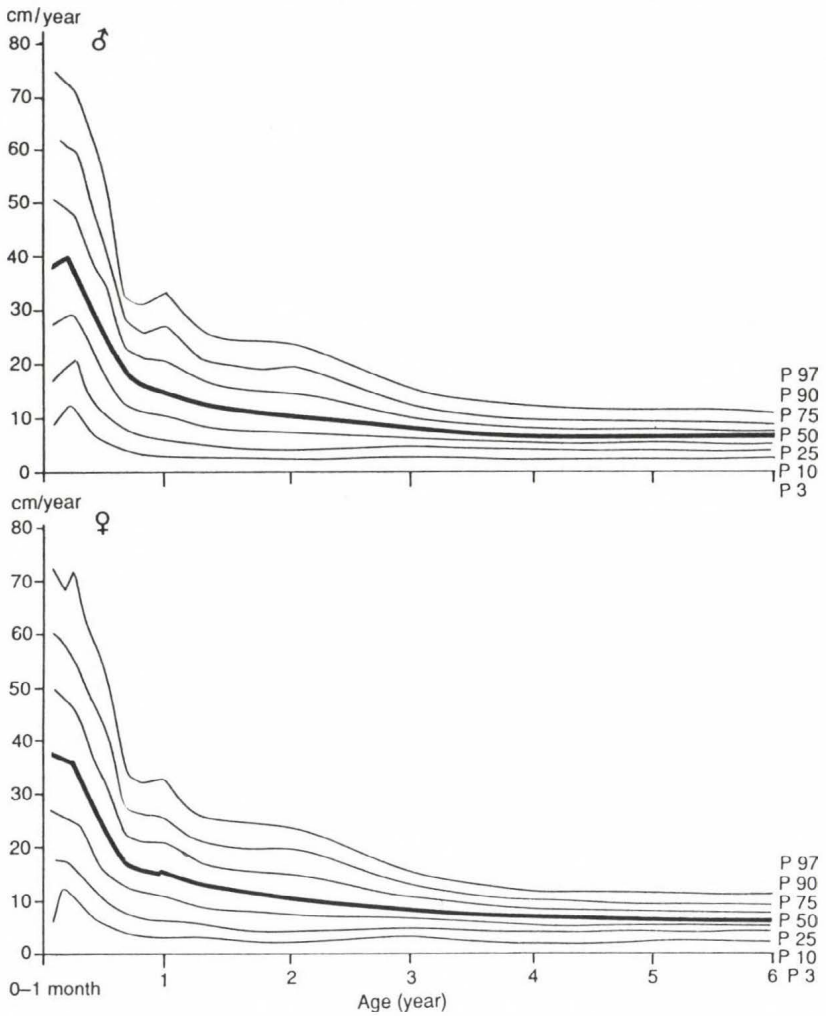

Fig. 4: Reference percentiles of the body height velocity calculated for one year by periods of the investigation from birth to the age of six years, boys and girls

months of the first year of age. In these periods percentile 50 is 24 cm/year, while during the 11th–12th months it is 15.02 cm/year (boys), and 16.20 cm/year (girls). In the course of the second year of age the difference between the extreme percentiles of the yearly growth velocity calculated for quarterly investigation periods is about 20 cm/year both for boys and girls. Percentile 50 shows values of 12.01 cm/year, and 12.80 cm/year respectively in the first quarter of year, and in the fourth quarter 10.41 cm/year both for boys and girls.

Also in case of body height (body length) we investigated the development of the growth velocities from birth to various ages. The means of the actual growth velocity values calculated for the periods investigated as well as their percentiles are presented in *Table 6*. The growth of the body length of the first month of life (50.81 cm for boys and

Table 6. **Reference values of body height velocity from birth**

Period studied (months completed)	N	Mean of height velocity (cm)	SD	Percentiles						
				3	10	25	50	75	90	97
Boys										
birth — 1	2776	3.3	1.5	0.7	1.4	2.2	3.2	4.2	5.2	6.2
birth — 3	2778	9.9	2.1	5.7	7.2	8.8	10.1	11.3	12.3	13.5
birth — 6	2693	17.4	2.4	12.4	14.4	15.9	17.5	18.9	20.2	21.7
birth — 12	2661	25.5	2.7	20.0	22.0	23.8	25.5	27.2	28.7	30.5
birth — 18	2461	31.6	3.1	25.7	27.8	29.6	31.8	33.7	35.5	37.3
birth — 24	2449	37.2	3.5	30.3	32.9	35.0	37.2	39.5	41.4	43.9
birth — 36	2238	45.5	3.9	38.4	40.7	43.0	45.5	48.0	50.5	53.3
birth — 48	2279	52.2	4.1	44.6	47.2	49.5	52.2	54.9	57.5	60.4
birth — 60	2331	58.9	4.5	50.5	53.3	56.0	58.9	61.8	64.6	67.6
birth — 72	2348	65.5	4.7	56.8	59.7	62.3	65.4	68.5	71.5	74.6
Girls										
birth — 1	2496	3.2	1.5	0.5	1.4	2.2	3.1	4.1	5.0	6.0
birth — 3	2479	9.3	2.0	5.0	6.7	8.2	9.4	10.6	11.7	12.8
birth — 6	2406	16.5	2.3	11.8	13.6	15.0	16.5	18.0	19.2	20.6
birth — 12	2359	24.6	2.7	19.4	21.3	23.0	24.7	26.3	27.8	29.6
birth — 18	2164	31.0	3.1	24.7	27.0	29.0	31.0	33.1	35.0	36.6
birth — 24	2179	36.8	3.5	30.0	32.5	34.7	36.8	39.0	41.0	43.3
birth — 36	1980	45.4	3.9	38.0	40.6	43.1	45.3	47.9	50.4	52.8
birth — 48	2014	52.2	4.1	44.3	47.0	49.6	52.3	55.0	57.4	60.3
birth — 60	2084	59.0	4.5	50.5	53.5	56.1	59.1	62.0	64.6	67.6
birth — 72	2086	65.6	4.8	56.8	59.5	62.4	65.7	68.6	71.6	74.3

50.14 cm for girls) give 6.49 per cent and 6.38 per cent, respectively. By the end of the third month the child grows by nearly one fifth of the body length at birth. By their age of one year boys will be longer by 50.19 per cent, and girls by 49.06 per cent than at birth. Children double their body length at birth at their ages of three and a half-for years. Boys will be higher by 128.91 per cent of their height at birth on the average and girls by 130.83 per cent.

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