

INFANT GROWTH CHARTS OF LIMB CIRCUMFERENCES

Ottó Wilhelm¹ and Annamária Zsáka²

¹St. George Hospital, Department of Paediatric, Syndromology, Székesfehérvár, Hungary;

²Eötvös Loránd University, Department of Biological Anthropology, Budapest, Hungary

Abstract: *In the epidemiological surveys upper arm circumference is usually used for the assessment of nutritional status and for screening the abnormality of nutritional status, while in the paediatric practice this limb circumference is used as an indicator of intrauterine growth restriction and abnormal development, especially an indicator of abnormal muscular development. Independently of the aim of the examination, both the screening or diagnostic work should only be done by considering the critical values of the examined body dimensions constructed for the given population. The growth charts and the centile distribution of limb circumferences not only on the upper arm, but also on the lower arm, thigh and calf are constructed and published for Hungarian infants in the present paper. The 3rd and 97th centiles are suggested as critical values for the developmental estimation and maturity determination. The uniqueness of this study is not only in the variety of the examined body dimensions, but also in the scaling of the growth charts, since the reference values are constructed both for chronological age and body length.*

Keywords: *Body development; Nutritional status; Musculo-skeletal development; Reference centiles.*

Introduction

Auxological studies evidenced that each healthy child follows along the same growth pattern from birth till sexual maturity independently from gender or the genetic origin (Falkner and Tanner 1978). Many environmental and genetic causes (and their interactions) of abnormal development have been already identified, but the medical science nowadays can treat and not prevent most of the developmental abnormalities. Nevertheless, our common aim is to help the clinicians in identifying growth retardation, i.e. the failure of an individual to develop at a normal rate, as early as possible, since the earlier the diagnosis, the more efficient treatment can be initiated (Gulmezoglu et al. 1997, Wollmann 1998, Garnera et al. 2000, Sood et al. 2002).

Growth charts are widely used for growth screening in paediatric care to provide information for evaluating growth status (Cole 1994, Kuczmariski et al. 2000). The use of local growth charts, which are based on nationally/regionally representative studies and regularly updated, always provides a more accurate assessment of growth and development than international growth references (Karlberg et al. 1999, Cole 2003).

Pediatricians usually consider body weight and length, head, chest and upper arm circumference and, occasionally, skinfold thicknesses on the trunk and the limbs in developmental assessment of infants (Alves et al. 1991, Biswas et al. 1994, Sharma and Bora 1998, Bhatia et al. 1999, Bodzsár 1999, Bettiol 2003, Burden et al. 2005, Nair et al. 2006, Susanne and Bodzsár 2004). The references are usually constructed for chronological age in these clinical assessments. The chronological age in infancy, especially in children born preterm with 6–10 weeks before the time, cannot provide the

appropriate reference point in time and its use could lead to methodological and not real biological difference in the developmental assessment. Therefore, charts for physiological variables (biological age, e.g. bone age; body length, etc.) are sometimes used in the developmental assessment (Gardosi et al. 1992).

The main purpose of the study was to construct growth charts of limb circumferences for assessment of body development in Hungarian children (from birth to 12 months of age). Limb circumferences can provide information not only on the nutritional status of children, but also on their musculo-skeletal development. Therefore, the use of these body dimensions can improve the developmental assessment (e.g. many congenital malformations associated with muscular dystrophy – their diagnosis rate and accuracy might be improved by using such growth charts; Beattie 1994, Ehrenkranz et al. 1999, Gokhale et al. 2003). Moreover, the growth charts are given not only for chronological age but also for body length.

Subjects and methods

Altogether 388 (201 boys and 187 girls) healthy and mature infants (all preterm, obese, dysmature and congenital malformed infants were excluded) were examined in the Department of Paediatric, St. George Hospital, Székesfehérvár in 2007. Infants were examined at 0, 1, 2, 3, 4, 5, 6, 9 and 12 months old of age (± 0.1 months).

The anthropometric measurements were performed by using the standardized techniques (IBP recommendations, Martin and Saller 1957, Weiner and Lourie 1969, Bettiol 2003) and standard anthropometric measuring devices. The measurements were performed on the middle part of upper and lower arms in relaxed position, the thighs and calf with contracted limbs.

The centile curves (3rd, 10th, 25th, 50th, 75th, 90th, 97th) were estimated by Cole's LMS method (1995). Growth charts are constructed both for chronological age and body length in the boys and the girls. Chi-square test was used for testing the sexual dimorphism in centile distributions: centiles were interchanged between the genders, namely, the distribution of girls' individual data by the boys' centile curves were compared to the empirical distribution (3, 10, 25, 50, 75, 90, 97%) and vice versa. Hypotheses were tested at 5% level of significance.

Results

Growth charts and centile values of upper and lower arm, thigh and calf circumference are presented in Figures 1–4 and Tables 1–8 for chronological age and in Figures 5–8 and Tables 9–12 for body length. By comparing the growth of the studied limb circumferences (for chronological age), it can be stated that (1) the growth of limb circumferences is very intensive in the first six postnatal months and (2) its growth tempo shows a considerable decrease around the age of 6–7 months in both genders. (3) In the second part of the first year after birth the growth rate does not change in either of the upper or lower limb circumferences (Figures 1–4, Tables 1–8). By considering the measuring accuracy of these circumferences (measured in one or half cm in the paediatrician practice), the sexual dimorphism, which could be assumed significant by surveying the graphs, is not significant in either of the circumferences ($p > 0.05$).

Table 1. Upper arm circumference centile values in boys from birth till 12-month of age.

Age (months)	P3	P10	P25	P50	P75	P90	P97
0	9.1	9.5	10.0	10.6	11.3	12.0	12.6
1	9.9	10.4	10.9	11.5	12.2	12.9	13.6
2	10.7	11.2	11.8	12.4	13.2	13.9	14.5
3	11.4	12.0	12.5	13.2	13.9	14.7	15.3
4	12.1	12.6	13.2	13.9	14.6	15.3	15.9
5	12.6	13.2	13.7	14.4	15.1	15.7	16.3
6	13.0	13.6	14.1	14.8	15.4	16.0	16.6
7	13.3	13.8	14.4	15.0	15.6	16.3	16.9
8	13.5	14.0	14.6	15.2	15.8	16.5	17.0
9	13.6	14.1	14.7	15.3	16.0	16.6	17.1
10	13.7	14.2	14.8	15.5	16.1	16.7	17.3
11	13.7	14.3	14.9	15.6	16.2	16.7	17.3
12	13.8	14.4	15.0	15.7	16.3	16.9	17.4

Table 2. Upper arm circumference centile values in girls from birth till 12-month of age.

Age (months)	P3	P10	P25	P50	P75	P90	P97
0	9.1	9.6	10.0	10.5	11.1	11.5	12.0
1	10.1	10.5	11.0	11.5	12.1	12.5	13.1
2	10.9	11.4	11.8	12.4	13.0	13.5	14.0
3	11.7	12.1	12.6	13.1	13.7	14.3	14.8
4	12.2	12.7	13.1	13.7	14.3	14.8	15.4
5	12.7	13.1	13.5	14.1	14.7	15.3	15.9
6	13.0	13.4	13.9	14.4	15.0	15.6	16.2
7	13.3	13.7	14.1	14.7	15.2	15.8	16.4
8	13.5	13.9	14.4	14.9	15.5	16.0	16.6
9	13.7	14.0	14.5	15.1	15.6	16.2	16.8
10	13.8	14.1	14.6	15.2	15.8	16.3	16.9
11	13.8	14.2	14.6	15.2	15.8	16.4	17.0
12	13.9	14.2	14.7	15.3	15.9	16.4	17.1

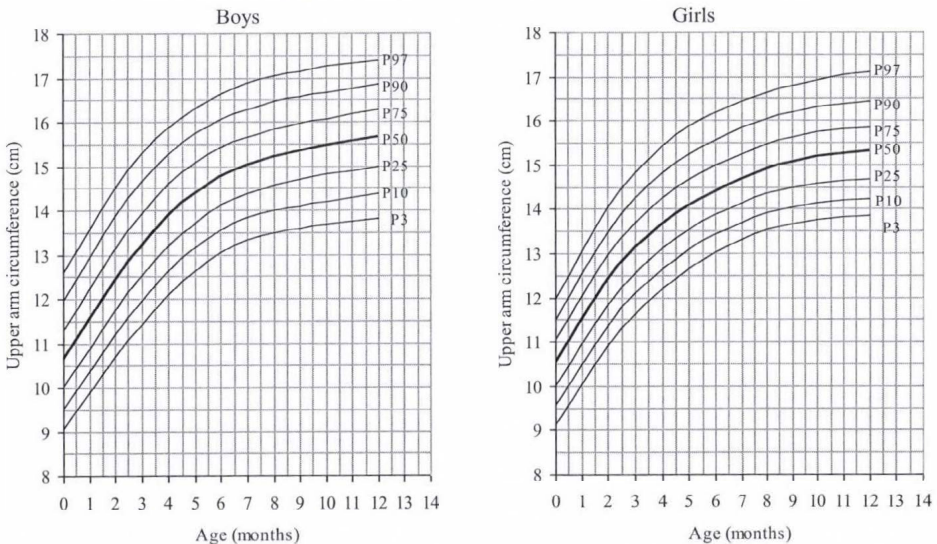


Figure 1: Upper arm circumference centile distribution in boys and girls from birth till 12-month of age.

Table 3. Lower arm circumference centile values in boys from birth till 12-month of age.

Age (months)	P3	P10	P25	P50	P75	P90	P97
0	8.4	8.8	9.2	9.7	10.3	10.9	11.5
1	9.1	9.6	10.0	10.6	11.2	11.8	12.5
2	9.9	10.3	10.8	11.4	12.1	12.7	13.4
3	10.6	11.0	11.5	12.1	12.8	13.5	14.2
4	11.1	11.6	12.1	12.7	13.4	14.1	14.8
5	11.6	12.1	12.6	13.2	13.9	14.6	15.2
6	11.9	12.4	13.0	13.6	14.3	14.9	15.6
7	12.1	12.7	13.2	13.9	14.5	15.2	15.9
8	12.3	12.8	13.4	14.0	14.7	15.3	16.1
9	12.4	13.0	13.6	14.2	14.8	15.5	16.2
10	12.5	13.1	13.6	14.2	14.9	15.6	16.3
11	12.5	13.1	13.7	14.3	15.0	15.6	16.4
12	12.5	13.1	13.7	14.4	15.0	15.7	16.4

Table 4. Lower arm circumference centile values in girls from birth till 12-month of age.

Age (months)	P3	P10	P25	P50	P75	P90	P97
0	8.4	8.7	9.1	9.5	10.0	10.4	10.9
1	9.2	9.5	9.9	10.3	10.8	11.3	11.9
2	9.9	10.3	10.7	11.1	11.7	12.2	12.8
3	10.6	11.0	11.4	11.8	12.4	13.0	13.6
4	11.2	11.5	11.9	12.4	13.0	13.5	14.2
5	11.7	12.0	12.4	12.9	13.4	14.0	14.7
6	12.0	12.4	12.7	13.2	13.8	14.3	15.0
7	12.3	12.6	13.0	13.5	14.0	14.6	15.2
8	12.4	12.8	13.2	13.6	14.1	14.7	15.3
9	12.5	12.9	13.3	13.7	14.3	14.8	15.4
10	12.6	12.9	13.3	13.8	14.3	14.8	15.5
11	12.6	12.9	13.4	13.9	14.4	14.9	15.6
12	12.6	13.0	13.4	13.9	14.4	14.9	15.6

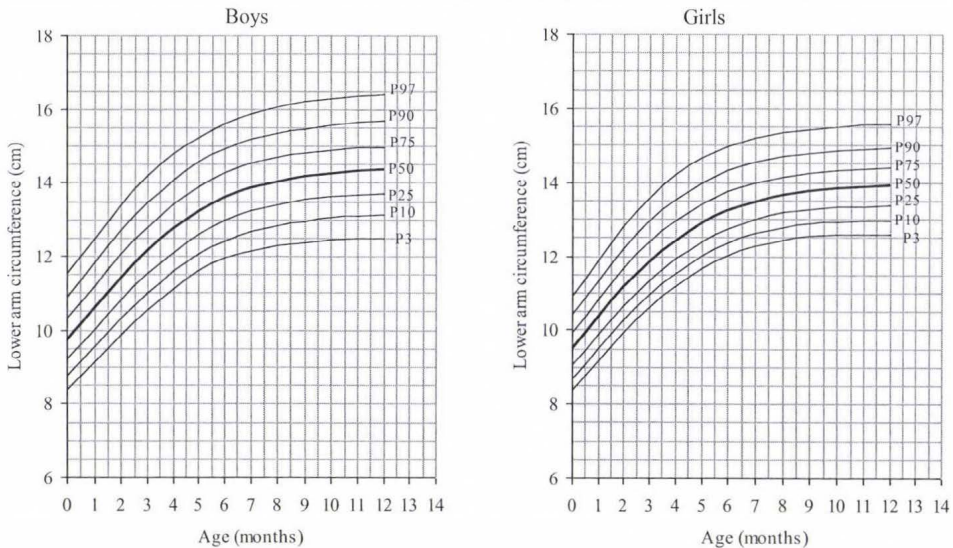


Figure 2: Lower arm circumference centile distribution in boys and girls from birth till 12-month of age.

Table 5. Thigh circumference centile values in boys from birth till 12-month of age.

Age (months)	P3	P10	P25	P50	P75	P90	P97
0	13.0	13.7	14.5	15.4	16.4	17.3	18.3
1	14.6	15.5	16.3	17.4	18.5	19.5	20.5
2	16.3	17.2	18.1	19.2	20.4	21.5	22.7
3	17.8	18.7	19.7	20.9	22.1	23.3	24.6
4	19.1	20.0	21.0	22.2	23.5	24.8	26.1
5	20.1	21.0	22.0	23.2	24.5	25.8	27.1
6	20.8	21.8	22.7	23.9	25.2	26.5	27.8
7	21.3	22.2	23.2	24.5	25.9	27.0	28.2
8	21.6	22.5	23.5	24.8	26.2	27.4	28.6
9	21.8	22.7	23.6	25.1	26.5	27.7	28.7
10	22.0	22.8	23.7	25.3	26.7	27.9	28.9
11	22.1	22.9	23.8	25.4	26.8	28.1	29.0
12	22.2	23.0	23.8	25.5	26.9	28.2	29.1

Table 6. Thigh circumference centile values in girls from birth till 12-month of age.

Age (months)	P3	P10	P25	P50	P75	P90	P97
0	13.5	14.1	14.7	15.4	16.1	16.8	17.4
1	15.4	16.0	16.7	17.4	18.2	18.9	19.6
2	17.3	17.9	18.6	19.3	20.1	20.9	21.6
3	18.9	19.5	20.2	21.0	21.8	22.6	23.4
4	20.2	20.8	21.5	22.3	23.2	23.9	24.8
5	21.1	21.7	22.4	23.3	24.1	25.0	25.8
6	21.7	22.3	23.1	23.9	24.8	25.7	26.6
7	22.1	22.8	23.5	24.4	25.3	26.3	27.2
8	22.4	23.1	23.9	24.7	25.7	26.7	27.7
9	22.6	23.3	24.1	25.0	26.0	27.0	28.1
10	22.8	23.5	24.2	25.2	26.2	27.2	28.3
11	22.9	23.6	24.4	25.3	26.3	27.4	28.5
12	23.0	23.7	24.5	25.4	26.4	27.5	28.7

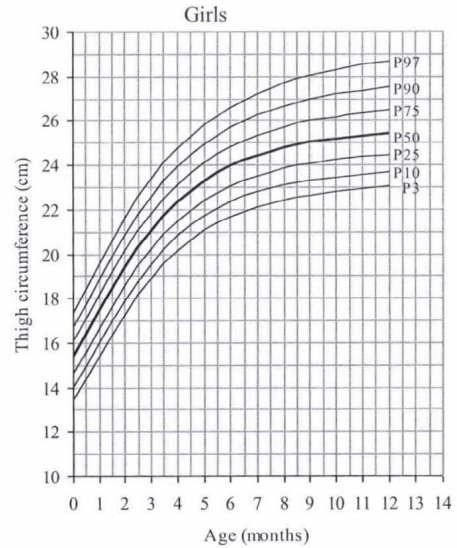
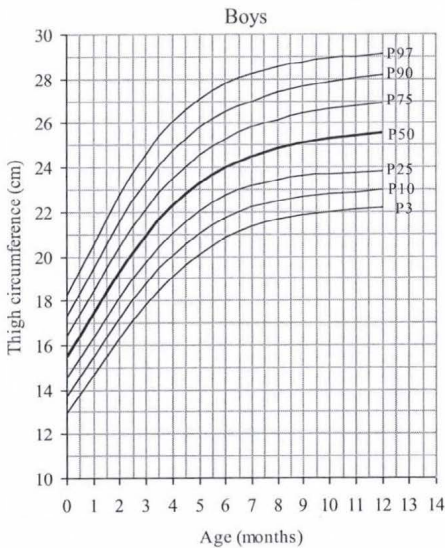


Figure 3: Thigh circumference centile distribution in boys and girls from birth till 12-month of age.

Table 7. Calf circumference centile values in boys from birth till 12-month of age.

Age (months)	P3	P10	P25	P50	P75	P90	P97
0	9.4	9.9	10.4	11.1	11.8	12.5	13.2
1	10.6	11.2	11.7	12.4	13.2	14.0	14.8
2	11.7	12.3	12.9	13.7	14.6	15.4	16.3
3	12.7	13.4	14.0	14.9	15.8	16.7	17.6
4	13.5	14.2	14.9	15.9	16.7	17.6	18.5
5	14.2	14.9	15.6	16.5	17.4	18.3	19.1
6	14.6	15.3	16.1	17.0	17.9	18.7	19.6
7	14.9	15.7	16.4	17.4	18.2	19.1	19.9
8	15.1	15.8	16.6	17.6	18.5	19.3	20.1
9	15.3	16.0	16.8	17.8	18.7	19.4	20.2
10	15.4	16.1	16.9	18.0	18.8	19.5	20.3
11	15.4	16.1	17.0	18.0	18.8	19.6	20.4
12	15.5	16.2	17.1	18.1	18.9	19.6	20.4

Table 8. Calf circumference centile values in girls from birth till 12-month of age.

Age (months)	P3	P10	P25	P50	P75	P90	P97
0	9.5	9.9	10.4	11.0	11.6	12.2	12.9
1	10.7	11.3	11.8	12.4	13.1	13.8	14.5
2	12.0	12.6	13.1	13.8	14.5	15.2	15.9
3	13.1	13.6	14.2	14.9	15.6	16.3	17.1
4	13.9	14.5	15.0	15.7	16.5	17.2	18.0
5	14.5	15.1	15.6	16.3	17.1	17.8	18.6
6	14.8	15.4	16.0	16.8	17.5	18.2	19.0
7	15.1	15.6	16.3	17.0	17.7	18.5	19.3
8	15.3	15.9	16.5	17.3	17.9	18.7	19.5
9	15.4	16.0	16.6	17.4	18.1	18.8	19.7
10	15.5	16.1	16.7	17.5	18.2	18.9	19.7
11	15.6	16.2	16.8	17.6	18.3	19.0	19.8
12	15.6	16.2	16.8	17.6	18.3	19.0	19.8

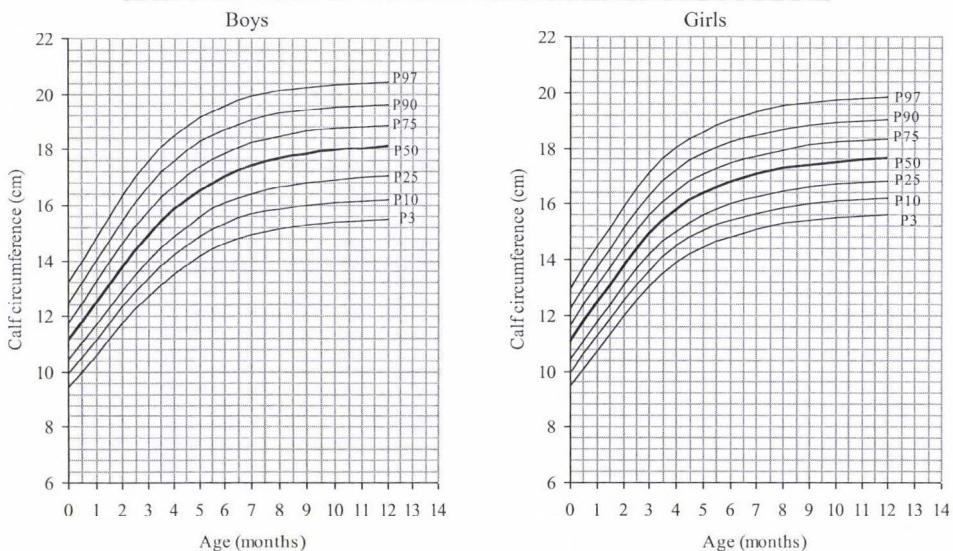


Figure 4: Calf circumference centile distribution in boys and girls from birth till 12-month of age.

Table 9. Upper arm circumference (cm) for body length (cm) centile values in boys and girls.

P3	P10	P25	P50	P75	P90	P97	Body length	P3	P10	P25	P50	P75	P90	P97
Boys								Girls						
9.0	9.3	9.7	10.2	10.8	11.4	12.3	51	8.2	8.8	9.4	10.0	10.7	11.2	11.7
9.2	9.6	10.0	10.4	11.1	11.7	12.6	52	8.5	9.1	9.7	10.4	11.0	11.6	12.1
9.5	9.8	10.2	10.7	11.3	12.0	12.9	53	8.8	9.5	10.1	10.8	11.4	12.0	12.6
9.7	10.0	10.4	11.0	11.6	12.3	13.2	54	9.2	9.8	10.4	11.1	11.8	12.4	13.0
9.9	10.3	10.7	11.2	11.9	12.6	13.5	55	9.5	10.1	10.7	11.4	12.2	12.8	13.5
10.1	10.5	11.0	11.5	12.2	12.9	13.8	56	9.8	10.4	11.1	11.8	12.5	13.2	13.9
10.4	10.8	11.2	11.8	12.5	13.2	14.1	57	10.1	10.7	11.4	12.1	12.9	13.6	14.3
10.6	11.0	11.5	12.1	12.8	13.5	14.4	58	10.4	11.0	11.7	12.4	13.2	13.9	14.7
10.9	11.3	11.8	12.4	13.1	13.8	14.7	59	10.7	11.3	11.9	12.7	13.5	14.2	15.0
11.1	11.5	12.0	12.7	13.4	14.1	14.9	60	11.0	11.6	12.2	12.9	13.7	14.5	15.3
11.3	11.8	12.3	12.9	13.7	14.4	15.2	61	11.2	11.8	12.4	13.2	14.0	14.8	15.6
11.6	12.0	12.6	13.2	13.9	14.7	15.5	62	11.5	12.0	12.6	13.4	14.2	15.0	15.9
11.8	12.3	12.8	13.5	14.2	14.9	15.7	63	11.7	12.3	12.8	13.6	14.4	15.2	16.1
12.0	12.5	13.0	13.7	14.4	15.2	15.9	64	11.9	12.5	13.0	13.7	14.5	15.3	16.2
12.2	12.7	13.3	13.9	14.7	15.4	16.1	65	12.1	12.6	13.2	13.9	14.7	15.5	16.4
12.4	12.9	13.5	14.1	14.9	15.6	16.3	66	12.3	12.8	13.4	14.0	14.8	15.6	16.5
12.6	13.1	13.7	14.3	15.1	15.7	16.5	67	12.5	13.0	13.5	14.1	14.9	15.7	16.6
12.7	13.3	13.8	14.5	15.2	15.9	16.6	68	12.6	13.1	13.6	14.3	15.0	15.8	16.7
12.8	13.4	14.0	14.7	15.4	16.0	16.7	69	12.8	13.2	13.7	14.3	15.1	15.8	16.8
13.0	13.5	14.1	14.8	15.5	16.1	16.8	70	12.9	13.3	13.8	14.4	15.1	15.9	16.8
13.1	13.7	14.2	14.9	15.6	16.2	16.9	71	13.0	13.4	13.9	14.5	15.2	16.0	16.9
13.2	13.8	14.4	15.0	15.7	16.3	16.9	72	13.1	13.5	14.0	14.6	15.3	16.0	16.9
13.3	13.9	14.5	15.1	15.8	16.4	17.0	73	13.2	13.6	14.0	14.6	15.3	16.1	17.0
13.5	14.0	14.6	15.2	15.9	16.5	17.0	74	13.3	13.7	14.1	14.7	15.4	16.1	17.0
13.6	14.1	14.7	15.3	16.0	16.5	17.1	75	13.4	13.8	14.2	14.8	15.4	16.2	17.1
13.7	14.3	14.8	15.4	16.1	16.6	17.1	76	13.5	13.9	14.3	14.8	15.5	16.2	17.1
13.9	14.4	15.0	15.6	16.2	16.7	17.2	77	13.6	14.0	14.4	14.9	15.5	16.3	17.1

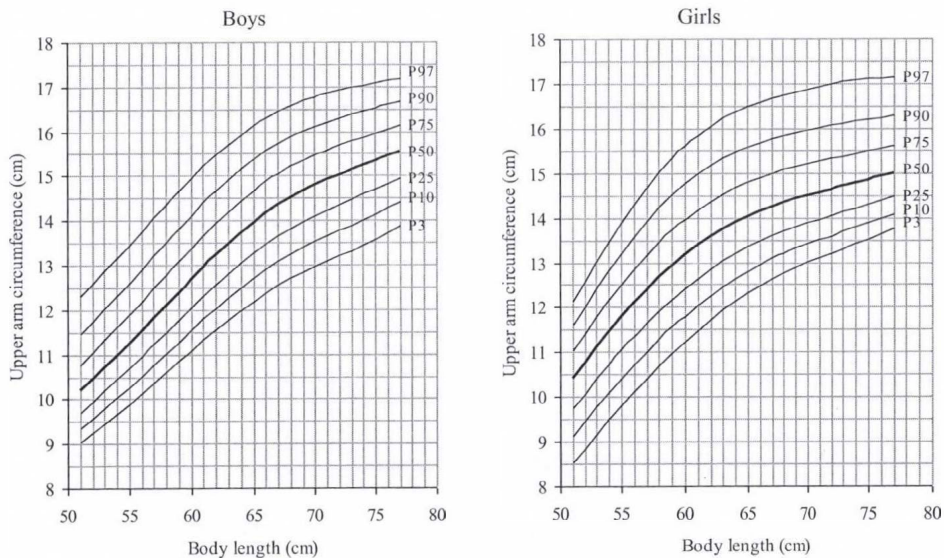


Figure 5: Upper arm circumference for body length centile distribution in boys and girls.

Table 10. Lower arm circumference (cm) for body length (cm) centile values in boys and girls.

P3	P10	P25	P50	P75	P90	P97	Body length	P3	P10	P25	P50	P75	P90	P97
Boys								Girls						
8.2	8.4	8.7	9.2	9.7	10.3	11.0	51	8.4	8.7	9.1	9.5	10.1	10.6	11.3
8.4	8.7	9.0	9.5	10.0	10.6	11.3	52	8.6	9.0	9.3	9.8	10.3	10.9	11.6
8.7	8.9	9.2	9.8	10.3	10.9	11.6	53	8.9	9.2	9.6	10.0	10.6	11.2	11.9
8.9	9.2	9.5	10.0	10.6	11.2	11.9	54	9.1	9.4	9.8	10.3	10.9	11.5	12.3
9.1	9.4	9.8	10.3	10.9	11.5	12.2	55	9.4	9.7	10.1	10.5	11.1	11.8	12.5
9.4	9.7	10.0	10.6	11.2	11.8	12.5	56	9.6	9.9	10.3	10.8	11.4	12.1	12.8
9.6	9.9	10.3	10.9	11.4	12.1	12.8	57	9.9	10.2	10.6	11.1	11.7	12.4	13.2
9.8	10.1	10.5	11.1	11.7	12.4	13.1	58	10.1	10.4	10.8	11.3	11.9	12.6	13.4
10.0	10.4	10.8	11.4	12.0	12.7	13.3	59	10.4	10.7	11.1	11.6	12.2	12.9	13.7
10.2	10.6	11.0	11.6	12.3	12.9	13.6	60	10.6	10.9	11.3	11.8	12.4	13.0	13.9
10.4	10.9	11.3	11.9	12.5	13.2	13.8	61	10.8	11.1	11.5	12.0	12.7	13.3	14.1
10.6	11.1	11.5	12.1	12.7	13.4	14.1	62	11.0	11.4	11.7	12.2	12.9	13.5	14.4
10.8	11.3	11.7	12.3	13.0	13.6	14.3	63	11.2	11.6	11.9	12.4	13.1	13.7	14.6
11.0	11.5	11.9	12.6	13.2	13.9	14.6	64	11.4	11.8	12.1	12.6	13.2	13.9	14.7
11.2	11.7	12.2	12.8	13.4	14.1	14.7	65	11.6	11.9	12.3	12.8	13.4	14.0	14.9
11.5	11.9	12.4	13.0	13.6	14.3	14.9	66	11.8	12.1	12.4	12.9	13.5	14.1	15.0
11.6	12.1	12.5	13.1	13.8	14.4	15.1	67	11.9	12.2	12.6	13.0	13.6	14.3	15.2
11.7	12.2	12.7	13.3	13.9	14.5	15.2	68	12.1	12.4	12.7	13.1	13.7	14.4	15.2
11.9	12.3	12.8	13.4	14.1	14.7	15.4	69	12.2	12.5	12.8	13.2	13.8	14.5	15.3
12.0	12.4	12.9	13.6	14.2	14.9	15.5	70	12.3	12.6	12.9	13.3	13.9	14.6	15.4
12.1	12.5	13.1	13.7	14.4	15.0	15.6	71	12.4	12.6	12.9	13.4	13.9	14.6	15.5
12.2	12.6	13.2	13.9	14.4	15.1	15.6	72	12.4	12.7	13.0	13.4	14.0	14.7	15.5
12.2	12.7	13.3	13.9	14.5	15.1	15.7	73	12.5	12.8	13.1	13.5	14.1	14.7	15.6
12.3	12.8	13.3	14.0	14.6	15.2	15.8	74	12.6	12.8	13.1	13.5	14.1	14.8	15.6
12.4	12.8	13.4	14.1	14.6	15.3	15.9	75	12.7	12.9	13.2	13.6	14.1	14.8	15.6
12.4	12.9	13.5	14.1	14.7	15.3	15.9	76	12.8	12.9	13.2	13.6	14.2	14.8	15.7
12.4	13.0	13.5	14.2	14.7	15.4	16.0	77	12.8	13.0	13.3	13.7	14.2	14.9	15.7

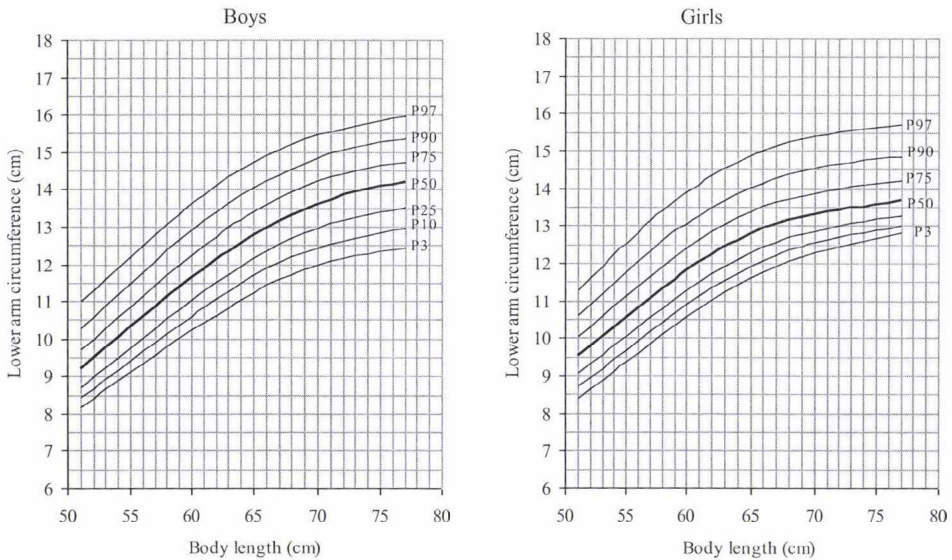


Figure 6: Lower arm circumference to body length centile distribution in boys and girls.

Table 11. Thigh circumference (cm) for body length (cm) centile values in boys and girls.

P3	P10	P25	P50	P75	P90	P97	Body length	P3	P10	P25	P50	P75	P90	P97
Boys								Girls						
12.7	13.2	13.9	14.6	15.4	16.2	17.0	51	12.4	13.4	14.3	15.4	16.4	17.2	18.1
13.1	13.7	14.4	15.2	16.0	16.8	17.6	52	13.0	14.0	15.0	16.1	17.1	18.0	18.9
13.6	14.2	14.9	15.7	16.6	17.4	18.3	53	13.6	14.6	15.7	16.8	17.8	18.8	19.7
14.1	14.7	15.4	16.3	17.1	18.0	18.9	54	14.2	15.3	16.3	17.4	18.6	19.6	20.6
14.6	15.2	16.0	16.8	17.7	18.6	19.5	55	14.9	15.9	16.9	18.1	19.3	20.3	21.3
15.1	15.8	16.5	17.4	18.3	19.2	20.2	56	15.4	16.5	17.6	18.8	20.0	21.0	22.1
15.6	16.3	17.0	17.9	18.9	19.8	20.8	57	16.0	17.1	18.2	19.4	20.6	21.7	22.8
16.1	16.8	17.6	18.5	19.5	20.5	21.5	58	16.6	17.7	18.8	20.0	21.3	22.4	23.5
16.6	17.3	18.1	19.1	20.1	21.1	22.2	59	17.2	18.2	19.3	20.6	21.8	23.0	24.1
17.1	17.9	18.7	19.6	20.7	21.7	22.8	60	17.7	18.8	19.9	21.1	22.4	23.5	24.7
17.6	18.4	19.2	20.2	21.3	22.3	23.4	61	18.2	19.2	20.3	21.6	22.9	24.0	25.2
18.1	18.9	19.7	20.7	21.8	22.9	24.0	62	18.7	19.7	20.8	22.0	23.3	24.5	25.7
18.6	19.4	20.2	21.3	22.4	23.5	24.6	63	19.1	20.1	21.2	22.4	23.7	24.9	26.1
19.0	19.8	20.7	21.8	22.9	24.0	25.2	64	19.5	20.5	21.5	22.7	24.0	25.2	26.4
19.5	20.3	21.2	22.2	23.4	24.5	25.7	65	19.8	20.8	21.8	23.0	24.3	25.5	26.7
19.8	20.6	21.6	22.7	23.8	24.9	26.1	66	20.1	21.1	22.1	23.3	24.5	25.7	26.9
20.2	21.0	22.0	23.0	24.2	25.3	26.5	67	20.3	21.3	22.3	23.5	24.7	25.9	27.1
20.5	21.3	22.3	23.4	24.5	25.7	26.8	68	20.6	21.5	22.5	23.7	24.9	26.1	27.3
20.8	21.6	22.6	23.7	24.9	26.0	27.1	69	20.8	21.7	22.7	23.8	25.1	26.2	27.5
21.1	21.9	22.8	23.9	25.1	26.3	27.3	70	20.9	21.9	22.9	24.0	25.2	26.4	27.6
21.3	22.1	23.1	24.2	25.4	26.5	27.5	71	21.1	22.0	23.0	24.1	25.4	26.5	27.8
21.4	22.3	23.2	24.3	25.5	26.7	27.7	72	21.3	22.2	23.1	24.3	25.5	26.7	27.9
21.6	22.4	23.4	24.6	25.7	26.8	27.8	73	21.5	22.4	23.3	24.4	25.6	26.8	28.0
21.7	22.6	23.6	24.7	25.8	26.9	27.9	74	21.6	22.5	23.4	24.5	25.8	26.9	28.2
21.8	22.7	23.7	24.8	25.9	27.1	28.0	75	21.8	22.6	23.6	24.7	25.9	27.1	28.2
21.9	22.8	23.8	24.9	25.9	27.1	28.0	76	21.9	22.8	23.7	24.8	26.0	27.1	28.3
22.1	22.9	23.8	25.1	26.0	27.2	28.1	77	22.1	22.9	23.8	24.9	26.1	27.2	28.4

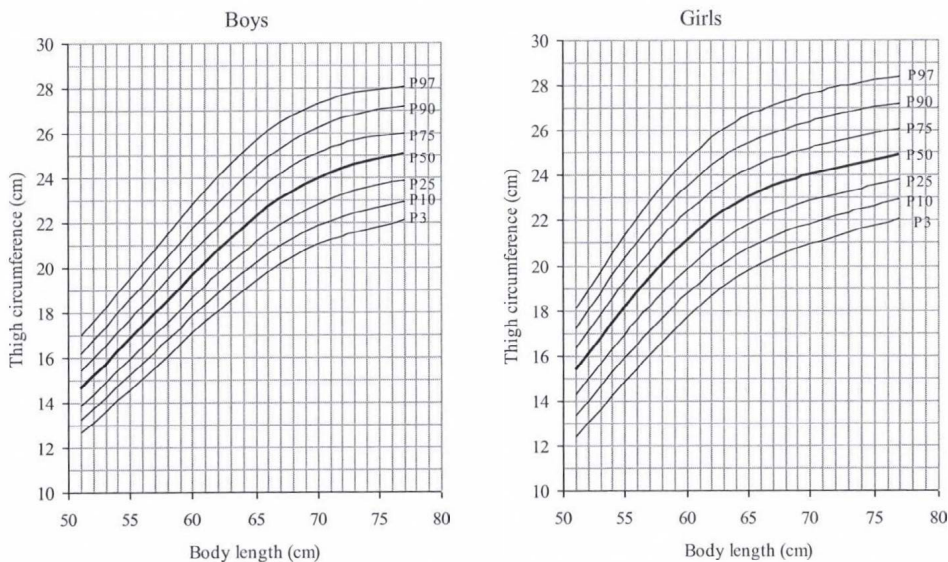


Figure 7: Thigh circumference to body length centile distribution in boys and girls.

Table 12. Calf circumference (cm) for body length (cm) centile values in boys and girls.

P3	P10	P25	P50	P75	P90	P97	Body length	P3	P10	P25	P50	P75	P90	P97
Boys								Girls						
9.3	9.6	10.0	10.5	11.2	11.9	12.8	51	9.0	9.7	10.4	11.4	12.4	13.4	14.5
9.6	10.0	10.4	10.9	11.6	12.3	13.3	52	9.4	10.1	10.8	11.8	12.8	13.8	15.0
9.9	10.3	10.7	11.3	12.0	12.8	13.7	53	9.8	10.5	11.2	12.2	13.2	14.3	15.4
10.2	10.7	11.1	11.7	12.4	13.2	14.1	54	10.2	10.9	11.6	12.6	13.6	14.7	15.8
10.6	11.0	11.5	12.1	12.9	13.7	14.6	55	10.6	11.3	12.0	13.0	14.0	15.1	16.3
10.9	11.4	11.9	12.5	13.3	14.1	15.0	56	11.0	11.7	12.4	13.4	14.4	15.5	16.7
11.2	11.7	12.3	12.9	13.7	14.5	15.4	57	11.4	12.1	12.8	13.8	14.8	15.9	17.1
11.6	12.1	12.7	13.4	14.1	15.0	15.9	58	11.8	12.5	13.2	14.2	15.2	16.3	17.4
11.9	12.4	13.0	13.7	14.6	15.4	16.3	59	12.2	12.9	13.6	14.5	15.6	16.6	17.8
12.2	12.8	13.4	14.1	15.0	15.8	16.7	60	12.6	13.2	14.0	14.9	15.9	16.9	18.1
12.5	13.1	13.7	14.5	15.3	16.1	17.0	61	12.9	13.6	14.3	15.2	16.2	17.2	18.3
12.8	13.4	14.1	14.8	15.7	16.5	17.4	62	13.2	13.9	14.6	15.5	16.5	17.5	18.6
13.1	13.7	14.4	15.2	16.0	16.8	17.7	63	13.5	14.1	14.8	15.8	16.7	17.7	18.7
13.4	14.0	14.7	15.5	16.3	17.1	18.0	64	13.7	14.3	15.1	15.9	16.9	17.8	18.9
13.7	14.3	15.0	15.8	16.7	17.4	18.2	65	13.9	14.5	15.2	16.1	17.1	18.0	19.1
14.0	14.6	15.3	16.1	16.9	17.7	18.5	66	14.0	14.7	15.4	16.3	17.2	18.1	19.1
14.2	14.9	15.6	16.4	17.2	17.9	18.7	67	14.2	14.8	15.6	16.4	17.3	18.2	19.2
14.4	15.1	15.8	16.6	17.4	18.1	18.8	68	14.3	14.9	15.7	16.6	17.5	18.3	19.4
14.6	15.3	16.0	16.8	17.6	18.3	18.9	69	14.5	15.1	15.8	16.7	17.6	18.3	19.5
14.8	15.5	16.2	17.0	17.7	18.4	19.1	70	14.6	15.2	15.9	16.8	17.7	18.4	19.6
15.0	15.7	16.4	17.1	17.9	18.5	19.2	71	14.7	15.3	16.1	16.9	17.7	18.5	19.6
15.2	15.9	16.5	17.3	18.0	18.6	19.3	72	14.8	15.4	16.1	17.0	17.8	18.5	19.7
15.3	16.0	16.7	17.4	18.1	18.7	19.4	73	14.8	15.5	16.2	17.1	17.9	18.6	19.8
15.5	16.1	16.8	17.5	18.2	18.8	19.5	74	14.9	15.6	16.3	17.1	17.9	18.7	19.9
15.6	16.3	16.9	17.6	18.3	18.9	19.5	75	15.0	15.7	16.3	17.2	18.0	18.8	19.9
15.8	16.4	17.0	17.7	18.4	19.0	19.6	76	15.1	15.7	16.4	17.3	18.1	18.9	20.0
15.9	16.5	17.1	17.8	18.5	19.0	19.7	77	15.2	15.8	16.4	17.4	18.1	18.9	20.0

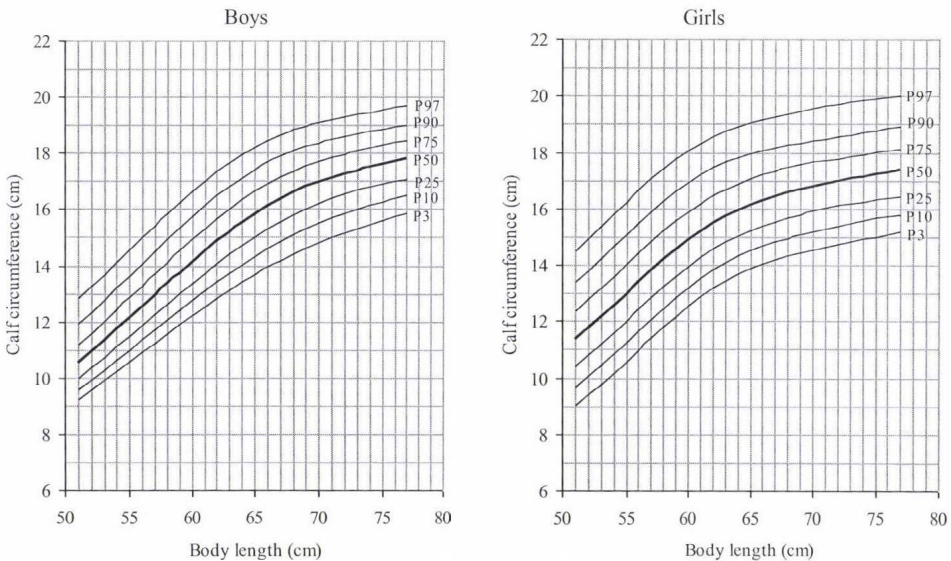


Figure 8: Calf circumference to body length centile distribution in boys and girls.

The growth of the studied limb circumferences for body length also shows a decrease by body length in both genders, but in this case a sexual dimorphism appears: around 70–72 cm body length in the boys and around 65–67 cm body length in the girls (Figs 5–8, Tables 9–12. The statistical analysis of this assumed sexual difference does not confirm this tendency ($p>0.05$).

Conclusions

Retarded infant body development could be an outcome of retardation both in intrauterine and postnatal growth, as well as perinatal complications (de Bruina et al. 1998, Embleton et al. 2001, Kanaka-Gantenbein and Mastorakos 2003). The aim of the practicing paediatricians is first to find the genetic or environmental factors that led to the abnormal growth and then treat this outcome. Growth charts and references are the easiest tools for this diagnostic and treating process.

Infant growth charts are appropriate tools not only for screening growth retardations, but also can be used for diagnose abnormal muscular development. To get developmental estimation and maturity determination as precise as possible, the authors suggest (1) the examination of all the studied limb circumferences both for age and body length; and (2) the 3rd and 97th centile values as critical values of abnormal intrauterine growth and development.

The presented results are based on the analysis of more than 380 infants' measurements. Our further aim is to extend our sample to make our growth charts as precise as possible and to give a really useful tool for screening retarded, delayed growth and musculo-skeletal development in infants.

*

Acknowledgement: The authors express their thanks to Robert Wilhelm MD for measurements in his praxis.

References

- Alves, J.G., Lima, G.M., Azevedo, G.N., Cabral, V.B., Moggi, R.S., Nunes, R. (1991): Evaluation of newborn arm circumference as an indicator of low birth weight. *Bull. Pan. Am. Health Organ.*, 25(3): 207–209.
- Beattie, R.B: (1994): Practical assessment of neonatal nutrition status beyond birthweight: an imperative for the 1990s. *BJOG*, 101(10): 842–846.
- Bettiol, H. (2003): Neonatal anthropometry and neonatal outcome. *Sao Paulo Med. J.*, 121(4): 147–148.
- Bhatia, R.C., Pooni, P.A., Singh, H., Singh, D. (1999): Mid-arm circumference for detecting malnutrition during infancy. *Indian J. Pediatr.*, 66(6): 843–848.
- Biswas, A.B., Sengupta, B., Manna, A., Mondal, N.C., Palodhi, P.K., Sarkar, S. (1994): Comparative usefulness of arm, thigh and calf circumference for screening low birth weight infants. *J. Trop. Pediatr.*, 40(5): 312–313.
- Burden, S.T., Stoppard, E., Shaffner, J., Makin, A., Todd, C. (2005): Can we use mid upper arm anthropometry to detect malnutrition in medical inpatients? A validation study. *J. Hum. Nutr. Diet.*, 18(4): 287–294.
- Bodzsár, É.B. (1999): A tápláltsági állapot becslése az antropometria eszközeivel. *Anthropologiai Közlemények*, 40: 83–95.
- Cole, T.J. (1994): Do growth chart centiles need a face lift? *BMJ*, 308: 641–644.
- Cole, T.J. (2003): The secular trend in human physical growth: a biological view. *Econom. Hum. Biol.*, 1(2): 161–168.

- de Bruina, J.P., Dorlanda, M., Bruinsea, H.W., Splietb, W., Nikkelsb, P.G.J., Te Veldea, E.R. (1998): Fetal growth retardation as a cause of impaired ovarian development. *Early Human Development*, 51(1): 39–46.
- Ehrenkranz, R.A., Younes, N., Lemons, J.A., Fanaroff, A.A., Donovan, E.F., Wright, L.L., Katsikiotis, V., Tyson, J.E., Oh, W., Shankaran, S., Bauer, C.R., Korones, S.B., Stoll, B.J., Stevenson, D.K., Papile, L-A. (1999): Longitudinal growth of hospitalized very low birth weight infants. *Pediatrics*, 104(2): 280–289.
- Embleton, N.E., Pang, N., Cooke, R.J. (2001): Postnatal malnutrition and growth retardation: An inevitable consequence of current recommendations in preterm infants? *Pediatrics*, 107(2): 270–273.
- Falkner, F., Tanner, J.M. (1978, Eds.): *Human growth*. New York: Plenum Press.
- Gardosi, J., Chang, A., Kalyan, B., Sahota, D., Symonds, E.M. (1992): Customised antenatal growth charts. *The Lancet*, 339(8788): 283–287.
- Garnera, P., Panpanichb, R., Logan, S. (2000): Is routine growth monitoring effective? A systematic review of trials. *Arch. Dis. Child.*, 82: 197–201.
- Gokhale, R., Kirschner, B.S. (2003): Assessment of growth and nutrition. *Best Practice and Research Clinical Gastroenterology*, 17(2): 153–162.
- Gulmezoglu, M., de Onis, M., Villar, J. (1997): Effectiveness of Interventions to Prevent or Treat Impaired Fetal Growth. *Obstet. Gynecol. Surv.*, 52(2): 139–148.
- Kanaka-Gantenbein, C., Mastorakos, G. (2003): Endocrine-Related Causes and Consequences of Intrauterine Growth Retardation. *Annals of the New York Academy of Sciences*, 997: 150–157
- Karlberg, J., Cheung, Y.B., Luo, Z.C. (1999): An update on the update of growth charts. *Acta Paediatr.*, 88: 797–802.
- Kuczmariski, R.J., Ogdén, C.L., Grummer-Strawn, L.M., Flegal, K.M., Guo, S.S., Wei, R., Mei, Z., Curtin, L.R., Roche, A.F., Johnson, C.L. (2000): CDC growth charts: United States. *Adv. Data.*, 8(314): 1–27.
- Martin, R., Saller, K. (1957): *Lehrbuch der Anthropologie I–IV*. Fischer Verlag, Stuttgart
- Nair, R.B., Elizabeth, K.E., Geetha, S., Varghese, S. (2006): Mid arm circumference (MAC) and body mass index (BMI) – the two important auxologic parameters in neonates. *J. Trop. Pediatr.*, 52(5): 341–345.
- Sharma, J.N., Bora, P. (1998): Mid arm circumference as an index of protein energy malnutrition between 6 to 12 months age. *Indian Pediatr.*, 35(10): 1005–1008.
- Şood, S.L., Saiprasad, G.S., Wilson, C.G. (2002): Mid arm circumference at birth: a screening method for detection of low birth weight. *Indian Pediatr.*, 39(9): 838–842.
- Susanne, C., Bodzsár, É. B. (2004): On physique and body composition. *Biennial Books of EAA, Vol. 4*. 9–40.
- Torres-Pereyra, J., Bloomfield, J., Torres, J. (1993): Perimeters of the arm and the thorax as indicators of low birth weight. *Rev. Chil. Obstet. Ginecol.*, 58(3): 228–230.
- Virdi, V.S., Jain, B.K., Singh, H. (2001): Calf circumference for identification of low birth weight babies. *Indian Pediatr.*, 38(8): 934–935.
- Weiner, J.S., Lourie, J.A. (1969, Eds): *Human Biology. A Guide to field Methods*. IBP Handbook, Oxford, Edinburgh:Blackwell Sci. Publ., p. 1–76.
- Wollmann, H.A: (1998): Intrauterine growth restriction: Definition and etiology. *Horm. Res.*, 49: 1–6.

Mailing address: Annamária Zsákai
 Eötvös Loránd Tudományegyetem, Embertani Tanszék
 Pázmány Péter sétány 1/c.
 1117 Budapest
 Hungary
 zsakaia@elte.hu