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ORIGINAL ARTICLE

Norm Values of Head Circumference in Turkish Children

Türk Çocuklarında Baş Çevresi Normal Değerleri

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ABSTRACT

Objective: Measuring head circumference is a quick, simple, cheap, noninvasive and reliable procedure for determining underlying brain size and provides information about risk for medical problems. Growth percentages of head vary from one community to another.
Methods: We aim to create head circumference growth curves for children aged 0-18 years in Turkish community. Measurements were performed by the same person using a rigid and calibrated tape meter. In addition, the parents were asked to fill out a questionnaire with variables that could affect children's growth.
Results: Data analysis has shown that there is no relationship between the children's head circumference and whether there is someone with a large/small head circumference in their families, or the average monthly income of their families and the parent's education level. Only the independent variables child's school performance, birth weight, nutrition, smoking are significantly effective on the HC measures of boys at alpha=0.05 level. For girls, only the independent variables birth weight and nutrition form are significantly important in explaining the variability of HC at the level of alpha=0.05. One gram increase in birth weight causes a 0.001 cm increase in the HC of both genders. In addition, head circumference growth curves were created for both genders to include all children aged 0-18.
Conclusions: Our study offers recent and gender-specific head circumference norms. These new values can be used more effectively in child follow-up.

Keywords:children, head circumference, norm values, growth curves

ÖZ

Genel Bilgiler: Baş çevresi ölçümü, beyin hacmi ve ilişkili olabilecek sorunları belirlemede hızlı, basit, ucuz, non- invaziv ve güvenilir bir yöntemdir ve olası medikal problem risklerinin tanınma ve takip sürecinde bilgi sağlar. Baş çevresi büyümesi toplumlar arasında ve cinsiyete göre değişkenlik gösterebilir.
Yöntemler: Türkiye'de yaşayan 0-18 yaş arası çocuklar için baş çevresi büyüme eğrileri oluşturmak hedeflendi. Ölçümler aynı kişi tarafından kalibre edilmiş, esnemeyen bir mezura kullanılarak yapılmıştı. Ayrıca ebeveynlerden çocukların büyümesini etkileyebilecek değişkenleri içeren bir anket doldurmaları istendi.
Bulgular: Veri analizi, çocukların baş çevresi ile ailelerinde baş çevresi büyük/küçük olan birinin olup olmadığı, ailelerinin ortalama aylık geliri, ebeveynin eğitim düzeyi arasında bir ilişki olmadığını göstermiştir. Erkek çocuklar için çocuğun okul başarısı, doğum ağırlığı, beslenmesi, annenin sigara içmesi bağımsız değişkenler olarak belirlenmiştir ve alfa değeri 0,05 idi. Kızlar için doğum ağırlığı ve beslenme şekli bağımsız değişkenlerdi ve alfa değeri 0,05 idi. Doğum ağırlığındaki bir gram artışın, her iki cinsiyette baş çevresinde 0,001 cm'lik bir artışa neden olduğu gösterildi. Ayrıca her iki cinsiyet için 0-18 yaş arası tüm çocukları kapsayacak şekilde baş çevresi büyüme eğrileri oluşturuldu.
Sonuçlar: Güncel ve cinsiyete özgü veriler ile oluşturulmuş baş çevresi büyüme eğrilerinin kullanılmasını gerektiğini önermekteyiz. Bu yeni değerler çocuk takibinde daha etkin olarak kullanılabilecektir.

Anahtar Kelimeler: çocuk, baş çevresi, normal değerleri, büyüme eğrileri

Introduction

Physical growth of babies and children is an important determinant of health and disease conditions. Growth curves serve to the physician to determine at what point the child deviates from normal measurements and thus to guide the examination by considering the child's nutritional and general health status.

Height, weight and head circumference (HC) are the anthropometric variables frequently used to monitor growth and development (1). There are additional numbers of other characteristics to asses and monitor growth (2,3). Since the normal values of any society may be different from other society's norms, many countries have attempted to specify the normal values of their own societies. A single international standard for HC may put many children at risk for misdiagnosis of macrocephaly or microcephaly. The findings in the studies suggest that the use of the unique international standard for the head circumference is not correct (4).

Although HC measures skull size, it also typically reflects overall brain volume and has been described as a "widely used proxy of neural growth and brain size". Brain size outside of normal values is an important risk factor for cognitive and motor delay (5).

Measuring HC is a quick, simple, cheap, noninvasive, and reliable procedure for determining underlying brain size, and it can provide information on risk for some medical and neurological problems. However, HC measurements are often considered to be difficult even by professionals due to individual differences in head shape, hair styles and texture, and subject cooperation as well as examiner differences in tape

measure placement and tautness. Moreover, Sullivan stated that the authors are unaware of standardized guidelines for measuring HC and different agencies recommend different tape measure tools and techniques, although there appears to be consensus that the tape measure must be pulled snugly and that the maximum distance around the head should be recorded (6).

While HC is often measured in infants at risk (eg, preterm or low-birth-weight infants, or those with known genetic disorders), few clinicians include serial HC measurements within routine well-baby checkups or as part of regular care for infants and children admitted to hospital for reasons other than growth concerns (i.e., opportunistic growth measurements) (5). Holden recently pointed out that "the time has arrived for the measurement of head circumference to receive the same status and acceptance as obtaining height and weight measurements during routine well-child evaluations" (7).

HC is, thus, a major diagnostic and prognostic marker used to help identifying symmetric or asymmetric growth, microcephaly (<2 SDs below the mean or <10th percentile) and macrocephaly (>2 SDs above the mean or >90th percentile), all of which are associated with a number of etiologies that require additional investigation. It is therefore essential that the clinician be provided with trustworthy and representative reference growth curves (8). In this study, we tried to determine the normal values of HC of children of our society.

Materials and methods

Children included in the sample of this study have the following characteristics. The child has no congenital deformity, chronic illness, or is not on medication. The family's income is high enough to meet the child's basic needs. The child's gestational age should be 38-42 weeks if she/he is younger than 2 years old, and the child was not born as a result of multiple pregnancies.

In this study, the children whose head circumference was measured were selected among children who were admitted to the emergency and general pediatric services of Meram Medical Faculty Hospital of Necmettin Erbakan University,Konya Training and Research Hospital, Dr. Faruk Sukan Maternity and Children Hospital, and who were attending the courses of The Presidency of Religious Affairs, family health centers and nursery.

A questionnaire sheet was also filled out by the parents about situations referred to in the first paragraph.

Nutritional status of children under 2 years of age was recorded as breastfeeding, formula feeding, mixed (breastfeeding + supplementary food), and supplementary food. Their birth weights were recorded. Smoking at home was asked for less than 2 years of age in the period before and after childbirth due to its effect on growth.

All measurements were performed by the same person using a same set tape measure after removing hair clips and undoing plaits, if any. The measurements of HC were conducted above the ears and slightly above the eyebrows in order to capture the maximum distance around the head, and to pull the tape measure tightly. Measurements were made with an inflexible tape measure with a width of 1.5 cm and a length of 150 cm. The reliability of the tape measure was tested in the calibration laboratory.

Prior to the measurements, a preliminary study was performed to test the intra and inter reliability of the physician who conducts all measurements. The reliability test results showed intra-rater and inter-rater reliability with 95% confidence.

Statistical review

Before estimating the growth curves for HC, we investigated any outliers that could affect the curve estimates. After dropping from the 119 outlier dataset, the total number of observations decreased to 5522, with 2961 male (53.62%) and 2561 (46.37%) female.

In this study, the growth curves were estimated by LMS method suggested in Tim Cole's article 'Smoothing reference centile curves: The LMS method and penalized likelihood', published in 1992 (9). At first stage, the estimation of LMS parameters was calculated for each group. The parameter L denotes optimum lambda value of Box-Cox transformation to normalize the HC distribution; M is the median value of HC measurement for corresponding age group, and S refers to the generalized coefficient of variation. Subsequently, in the second step, a nonparametric smoothing procedure was performed using the Lowess method based on these statistics. This procedure was repeated for ranges of 1% to 99% for different ages and genders.

The partial correlation coefficients were calculated with Spearman's Rho by controlling child's age to investigate the relationship between HC and the demographic and physical characteristics of the child and the child's family.

Stata 13 package program was used for statistical analysis.

Results

The statistical analysis was conducted by using totally 5522 HC measurements of children. Of those the 2961 were boys (53.6%); while the number of girl was 2561 (46.4%). The distribution of children in the study by gender and age group is shown in **Table 1.**

Ages of the children were recorded as day/month/year. Considering that HC growth is faster in the first years, the age categories are arranged accordingly.

Thus, the ages are grouped at intervals of 15 days for the first 6 months, 30 days for 6-12 months, 3 months for 3-5 years, and 6 months for the following years.

The percentage distributions according to gender and age variables of the children in the survey are given in **Table 2** and **Table 3**, respectively. The estimated HC growth curves for percentiles from 1% to 99% are given in Figures 1 and 2 for children in the first 5-year group and Figures 3 and 4 for children in all ages (0-19 years).

The profiles of the families and children in the survey are given in **Table 4**.

Distribution according to birth weights for children under two years was as follows: <2500 gr. (0.1%), 2500-2999 gr. (22.4%),3000-3499 gr. (53.1%), 3500-3999 gr. (20.6%), 4000-4599 gr. (3.8%).

According to the results of the regression analysis (**Table 5**) conducted by controlling the effect of the age variable, only the independent variables child's school performance, birth weight, nutrition form, smoking during pregnancy and smoking after birth are significantly effective on the HC measures of boys at alpha=0.05 level. On the other hand, for the girls, only the independent variables birth weight and nutrition form are significantly important in explaining the variability of HC at the level of alpha=0.05. In addition, one gram increase in birth weight causes a 0.001 cm increase in the HC of both boys and girls.

Following the regression analysis, multiple comparison analyzes by Tukey's method is performed to see the significance of the difference between the levels of meaningful categorical variables.

There is statistically significant difference in the HC measurements between some levels of school performance of the boys. Significant differences in HC at alpha = 0.05 level are observed between successful vs. failure, appreciation vs. failure, high achievement vs. failure, successful vs. pass, appreciation vs. pass and high achievement vs. pass success. These differences are positive in favor of the first of the pairs given above. It is noteworthy that as the level of success increases, the difference between the HC measurements also tends to increase.

No smoking during pregnancy period and no smoking after birth were found to cause an average decrease of 0.942 and 0.939 cm in the HC measurement of boys, respectively.

When looking at the children who are exposed to pre- and post-natal cigarettes; only 7 children (3 males) who were exposed to cigarettes in pregnancy were found. There was a child who exposed cigarettes only after birth. That is, the majority of those who were exposed to cigarettes during pregnancy continued to expose after birth. The majority of those who were not exposed to cigarette smoking during pregnancy were not exposed after birth. The end result is that the values of the group exposed to the cigarette actually represent the whole period before and after the birth. To determine the effect of encountering prenatal cigarette smoking, values of children aged 7 days or less were examined (**Table 6**). Because they are very young, they can be thought of as having no post-natal effects. The p value of the groups in Table 6 was found as 0.3433 for boys, 0.3368 for girls. These results indicate that exposure to cigarette smoking in the prenatal period does not significantly affect the HC.

When the children in the first 24 months were divided into 6-month-old age groups, there was a significant difference in 0-6 month's group in boys and 18-24 months group in girls according to the nutrition form. Tukey's multiple comparison tests was used to understand which differences in nutritional patterns are important during this age. However, when these age periods were divided into subcategories in terms of nutrition, very few observations were found in some groups. For this reason, the power of the test is very low and it is not enough to say that there is a statistical difference. For this reason, we cannot say that there is a significant difference between HC measurements according to nutrition type in 0-6 month's old males. This statement is also true for 18-24 month old girls.

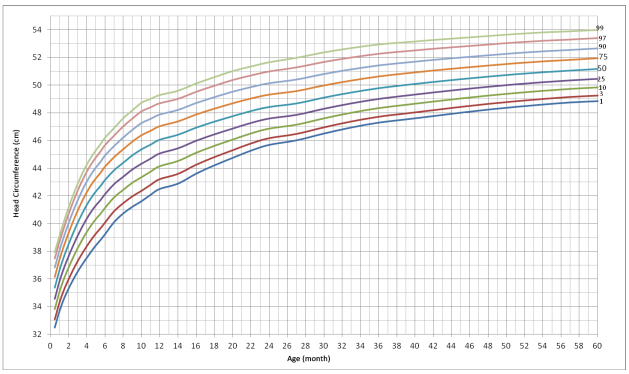

Figure 1: The head circumference curves limited to 1-99% for boys from birth to 5 years

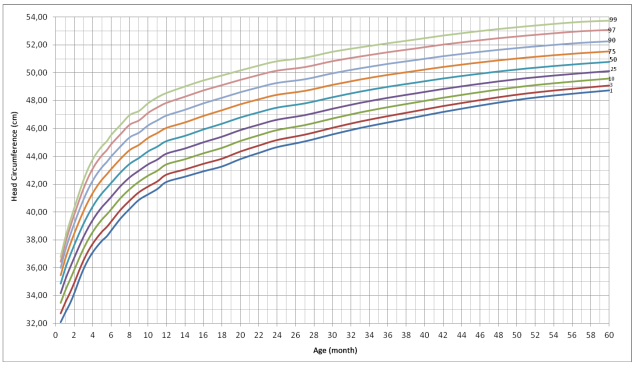

Figure 2: The head circumference curves limited to 1-99% for girls from birth to 5 years

Table 1. Distribution of the 5522 children by age and gender

Age	Boy		Girl		Total	
	Number	Percentage	Number	Percentage	Number	Percentage
0-15 days	107	1.94	101	1.83	208	3.77
1 months	26	0.47	24	0.43	50	0.91
1.5 months	20	0.36	15	0.27	35	0.63
2 months	8	0.14	6	0.11	14	0.25
2.5 months	10	0.18	6	0.11	16	0.29
3 months	11	0.20	8	0.14	19	0.34
3.5 months	5	0.09	9	0.16	14	0.25
4 months	13	0.24	8	0.14	21	0.38
4.5 months	12	0.22	14	0.25	26	0.47
5 months	10	0.18	7	0.13	17	0.31
5.5 months	9	0.16	10	0.18	19	0.34
6 months	26	0.47	10	0.18	36	0.65
7 months	28	0.51	18	0.33	46	0.83
8 months	21	0.38	12	0.22	33	0.60
9 months	26	0.47	16	0.29	42	0.76
10 months	18	0.33	12	0.22	30	0.54
11 months	14	0.25	7	0.13	21	0.38
12 months	11	0.20	10	0.18	21	0.38
13-14 months	45	0,81	31	0.56	76	1.38
15-16 months	29	0.53	22	0.40	51	0.92
17-18 months	28	0.51	35	0.63	63	1.14
19-20 months	38	0.69	37	0.67	75	1,36
21-22 months	31	0.56	20	0.36	51	0.92
23-24 months	33	0.60	30	0.54	63	1.14
2 years 3 months	55	1.00	33	0.60	88	1.59
2.5 years	52	0.94	37	0.67	89	1.61
2 years 9 months	48	0.87	42	0.76	90	1.63
3 years	49	0.89	25	0.45	74	1.34
3 years 3 months	57	1.03	27	0.49	84	1.52
3.5 years	27	0.49	22	0.40	49	0.89
3 years 9 months	38	0.69	30	0.54	68	1.23
4 years	35	0.63	34	0.62	69	1.25
4 years 3 months	77	1.39	49	0.89	126	2.28
4.5 years	58	1.05	30	0.54	88	1.59
4 years 9 months	46	0.83	34	0.62	80	1.45
5 years	35	0.63	29	0.53	64	1.16
5.5 years	100	1.81	65	1.18	165	2.99
6 years	68	1.23	70	1.27	138	2.50
6.5 years	85	1.54	66	1.20	151	2.73
7 years	41	0.74	64	1.16	105	1.90
7.5 years	96	1.74	77	1.39	173	3.13
8 years	47	0.85	61	1.10	108	1.96
8.5 years	72	1.30	59	1.07	131	2.37
9 years	54	0.98	57	1.03	111	2.01
9.5 years	65	1.18	62	1.12	127	2.30
10 years	52	0.94	60	1.09	112	2.03
10.5 years	65	1.18	73	1.32	138	2.50
11 years	50	0.91	40	0.72	90	1.63
11.5 years	80	1.45	76	1.38	156	2.83
12 years	72	1.30	72	1.30	144	2.61
12.5 years	75	1.36	76	1.38	151	2.73
13 years	91	1.65	66	1.20	157	2.84
13.5 years	79	1.43	79	1.43	158	2.86
14 years	81	1.47	62	1.12	143	2.59
14.5 years	71	1.29	56	1.01	127	2.30
15 years	43	0.78	52	0.94	95	1.72
15.5 years	67	1.21	64	1.16	131	2.37
16 years	37	0.67	30	0.54	67	1.21
16.5 years	50	0.91	49	0.89	99	1.79
17 years	52	0.94	56	1.01	108	1.96
17.5 years	56	1.01	66	1.20	122	2.21
18 years	44	0.80	35	0.63	79	1.43
18.5 years	58	1.05	76	1.38	134	2.43
19 years	54	0.98	32	0.58	86	1.56
Total	2961	53.62	2561	46.38	5522	100.00

Table 2. Percentile values of boys by age

Age	P 1	P 3	P 5	P 10	P 25	P 50	P 75	P 90	P 95	P 97	P 99
0-15 days	32.48	33.06	33.36	33.82	34.57	35.37	36.14	36.82	37.22	37.48	37.95
1 months	33.63	34.25	34.56	35.03	35.79	36.59	37.35	38.01	38.39	38.63	39.08
1.5 months	34.54	35.18	35.51	36.00	36.78	37.60	38.38	39.05	39.44	39.69	40.14
2 months	35.28	35.95	36.29	36.80	37.62	38.49	39.30	40.00	40.41	40.67	41.14
2.5 months	35.92	36.63	37.00	37.54	38.40	39.30	40.14	40.87	41.29	41.55	42.04
3 months	36.51	37.26	37.64	38.21	39.11	40.04	40.92	41.66	42.09	42.36	42.86
3.5 months	37.03	37.83	38.23	38.83	39.76	40.73	41.63	42.38	42.82	43.10	43.60
4 months	37.51	38.35	38.77	39.39	40.35	41.34	42.26	43.03	43.47	43.74	44.25
4.5 months	37.98	38.83	39.26	39.89	40.87	41.88	42.80	43.58	44.02	44.30	44.81
5 months	38.41	39.27	39.70	40.33	41.32	42.33	43.26	44.05	44.50	44.78	45.30
5.5 months	38.8	39.65	40.07	40.70	41.69	42.71	43.65	44.45	44.91	45.20	45.73
6 months	39.21	40.07	40.49	41.13	42.13	43.15	44.11	44.91	45.37	45.67	46.20
7 months	40.09	40.89	41.29	41.90	42.85	43.85	44.80	45.60	46.07	46.36	46.90
8 months	40.72	41.47	41.86	42.44	43.39	44.40	45.37	46.22	46.71	47.02	47.61
9 months	41.20	41.96	42.36	42.95	43.91	44.93	45.92	46.77	47.27	47.59	48.18
10 months	41.60	42.36	42.76	43.35	44.32	45.37	46.38	47.26	47.78	48.11	48.73
11 months	42.07	42.80	43.18	43.75	44.69	45.71	46.70	47.57	48.08	48.40	49.01
12 months	42.49	43.21	43.58	44.15	45.07	46.07	47.03	47.88	48.38	48.69	49.29
13-14 months	42.87	43.59	43.96	44.52	45.44	46.42	47.38	48.21	48.70	49.02	49.60
15-16 months	43.60	44.25	44.59	45.12	45.99	46.94	47.88	48.71	49.21	49.53	50.12
17-18 months	44.20	44.80	45.13	45.62	46.45	47.37	48.30	49.14	49.64	49.97	50.58
19-20 months	44.74	45.30	45.60	46.07	46.87	47.77	48.69	49.53	50.04	50.38	51.02
21-22 months	45.26	45.79	46.07	46.52	47.27	48.14	49.03	49.86	50.37	50.71	51.35
23-24 months	45.67	46.17	46.44	46.86	47.59	48.43	49.31	50.14	50.66	51.00	51.65
2 years 3 month	46.01	46.48	46.74	47.15	47.86	48.69	49.57	50.41	50.94	51.29	51.98
2.5 years	46.49	46.96	47.21	47.60	48.30	49.11	49.98	50.81	51.33	51.68	52.37
2 years 9 month	46.93	47.38	47.62	48.01	48.69	49.48	50.33	51.14	51.66	52.00	52.68
3 years	47.28	47.72	47.96	48.34	49.01	49.79	50.63	51.43	51.94	52.28	52.94
3 years 3 months	47.52	47.96	48.20	48.59	49.25	50.03	50.85	51.64	52.13	52.46	53.10
3.5 years	47.75	48.20	48.44	48.82	49.47	50.24	51.06	51.83	52.31	52.64	53.27
3 years 9 months	48.00	48.44	48.67	49.04	49.69	50.44	51.24	52.00	52.47	52.79	53.41
4 years	48.22	48.65	48.88	49.25	49.88	50.63	51.41	52.16	52.63	52.94	53.55
4 years 3 months	48.42	48.84	49.07	49.43	50.06	50.80	51.58	52.32	52.78	53.09	53.69
4.5 years	48.59	49.01	49.23	49.59	50.22	50.94	51.71	52.45	52.91	53.21	53.81
4 years 9 months	48.74	49.15	49.38	49.73	50.35	51.07	51.83	52.55	53.00	53.30	53.89
5 years	48.83	49.25	49.48	49.84	50.46	51.18	51.94	52.66	53.11	53.41	53.99
5.5 years	48.89	49.31	49.54	49.91	50.53	51.25	52.00	52.71	53.15	53.43	53.99
6 years	49.06	49.50	49.73	50.09	50.72	51.44	52.19	52.88	53.31	53.59	54.14
6.5 years	49.19	49.63	49.87	50.24	50.87	51.59	52.32	53.00	53.42	53.69	54.21
7 years	49.31	49.77	50.01	50.39	51.02	51.74	52.47	53.13	53.53	53.79	54.29
7.5 years	49.46	49.93	50.17	50.56	51.20	51.91	52.63	53.27	53.66	53.91	54.39
8 years	49.57	50.06	50.32	50.71	51.37	52.09	52.80	53.43	53.81	54.05	54.51
8.5 years	49.69	50.20	50.47	50.88	51.55	52.27	52.98	53.61	53.98	54.21	54.65
9 years	49.78	50.32	50.61	51.03	51.73	52.47	53.18	53.79	54.15	54.39	54.81
9.5 years	49.84	50.43	50.73	51.18	51.90	52.65	53.37	53.98	54.33	54.56	54.97
10 years	49.90	50.53	50.85	51.32	52.07	52.84	53.55	54.16	54.50	54.72	55.13
10.5 years	49.99	50.66	50.99	51.48	52.24	53.02	53.74	54.34	54.68	54.89	55.28
11 years	50.10	50.80	51.15	51.65	52.43	53.21	53.92	54.52	54.85	55.06	55.45
11.5 years	50.24	50.96	51.31	51.83	52.61	53.39	54.11	54.69	55.02	55.23	55.61
12 years	50.41	51.14	51.49	52.01	52.79	53.58	54.28	54.87	55.19	55.40	55.77
12.5 years	50.61	51.34	51.69	52.20	52.98	53.76	54.47	55.05	55.37	55.58	55.95
13 years	50.84	51.55	51.9	52.41	53.18	53.96	54.66	55.23	55.56	55.76	56.14
13.5 years	51.07	51.77	52.11	52.61	53.38	54.15	54.84	55.42	55.74	55.95	56.32
14 years	51.33	52.00	52.34	52.82	53.58	54.33	55.02	55.60	55.92	56.13	56.5
14.5 years	51.60	52.25	52.57	53.05	53.78	54.53	55.21	55.78	56.10	56.30	56.67
15 years	51.89	52.51	52.83	53.28	54.00	54.72	55.39	55.95	56.27	56.47	56.84
15.5 years	52.19	52.79	53.09	53.53	54.22	54.92	55.58	56.13	56.44	56.64	57.00
16 years	52.48	53.05	53.34	53.77	54.44	55.13	55.77	56.31	56.61	56.81	57.17
16.5 years	52.77	53.32	53.6	54.01	54.67	55.34	55.96	56.49	56.79	56.98	57.33
17 years	53.04	53.58	53.85	54.25	54.88	55.54	56.15	56.67	56.96	57.15	57.49
17.5 years	53.30	53.82	54.08	54.47	55.09	55.72	56.32	56.82	57.11	57.29	57.63
18 years	53.53	54.03	54.28	54.66	55.26	55.88	56.45	56.94	57.23	57.40	57.73
18.5 years	53.73	54.21	54.45	54.81	55.38	55.97	56.53	57.01	57.28	57.45	57.77
19 years	53.89	54.34	54.57	54.90	55.45	56.01	56.55	57.01	57.27	57.44	57.75
19.5 years	54.00	54.42	54.63	54.96	55.47	56.02	56.53	56.98	57.24	57.40	57.70

Table 3. Percentile values of girls by age

Ages	P 1	P 3	P 5	P10	P 25	P 50	P 75	P 90	P 95	P 97	P 99
0-15 days	32.09	32.72	33.03	33.48	34.17	34.85	35.47	35.98	36.26	36.44	36.77
1 month	32.77	33.50	33.86	34.37	35.15	35.94	36.64	37.22	37.55	37.76	38.13
1.5 months	33.42	34.19	34.57	35.13	35.99	36.84	37.62	38.27	38.64	38.87	39.29
2 months	34.20	34.95	35.33	35.89	36.77	37.67	38.50	39.21	39.62	39.87	40.34
2.5 months	35.12	35.79	36.15	36.68	37.53	38.45	39.33	40.10	40.55	40.83	41.37
3 months	35.93	36.56	36.89	37.40	38.25	39.18	40.10	40.92	41.41	41.73	42.32
3.5 months	36.60	37.21	37.54	38.04	38.89	39.84	40.79	41.65	42.17	42.51	43.15
4 months	37.13	37.75	38.08	38.60	39.46	40.42	41.39	42.28	42.81	43.15	43.81
4.5 months	37.57	38.21	38.55	39.07	39.95	40.93	41.91	42.79	43.32	43.67	44.32
5 months	37.95	38.60	38.95	39.48	40.37	41.36	42.34	43.23	43.75	44.10	44.74
5.5 months	38.25	38.93	39.28	39.83	40.73	41.73	42.71	43.59	44.11	44.44	45.08
6 months	38.68	39.33	39.68	40.21	41.11	42.10	43.10	44.00	44.54	44.89	45.55
7 months	39.54	40.16	40.49	41.01	41.87	42.84	43.82	44.71	45.25	45.60	46.26
8 months	40.23	40.83	41.15	41.65	42.50	43.47	44.46	45.37	45.92	46.28	46.97
9 months	40.87	41.42	41.72	42.18	42.98	43.89	44.82	45.70	46.23	46.59	47.26
10 months	41.27	41.84	42.14	42.62	43.43	44.37	45.33	46.22	46.77	47.13	47.83
11 months	41.65	42.20	42.50	42.97	43.77	44.70	45.67	46.58	47.15	47.52	48.24
12 months	42.16	42.69	42.98	43.43	44.20	45.10	46.04	46.93	47.48	47.85	48.56
13-14 months	42.54	43.06	43.34	43.79	44.57	45.48	46.44	47.34	47.91	48.29	49.02
15-16 months	42.92	43.46	43.76	44.22	45.02	45.94	46.90	47.81	48.37	48.74	49.46
17-18 months	43.27	43.83	44.13	44.60	45.41	46.34	47.31	48.20	48.75	49.11	49.81
19-20 months	43.80	44.34	44.64	45.10	45.89	46.79	47.73	48.61	49.14	49.49	50.17
21-22 months	44.24	44.77	45.06	45.50	46.28	47.17	48.09	48.96	49.49	49.84	50.53
23-24 months	44.66	45.17	45.45	45.88	46.63	47.50	48.41	49.27	49.8	50.15	50.84
2 years 3 months	45.07	45.56	45.82	46.24	46.96	47.81	48.70	49.54	50.06	50.41	51.09
2.5 years	45.57	46.04	46.30	46.71	47.42	48.25	49.13	49.96	50.49	50.84	51.52
2 years 9 months	46.03	46.50	46.75	47.15	47.84	48.65	49.51	50.32	50.83	51.17	51.83
3 years	46.43	46.88	47.13	47.52	48.20	49.00	49.84	50.64	51.14	51.48	52.13
3 years 3 months	46.80	47.24	47.48	47.86	48.52	49.30	50.12	50.92	51.41	51.75	52.40
3.5 years	47.18	47.61	47.84	48.20	48.84	49.60	50.41	51.19	51.69	52.03	52.68
3 years 9 months	47.53	47.93	48.15	48.51	49.12	49.86	50.66	51.44	51.93	52.27	52.93
4 years	47.85	48.24	48.45	48.79	49.39	50.10	50.88	51.65	52.15	52.48	53.15
4 years 3 months	48.14	48.51	48.71	49.04	49.61	50.31	51.08	51.84	52.33	52.67	53.34
4.5 years	48.36	48.72	48.92	49.24	49.80	50.49	51.25	52.01	52.50	52.84	53.52
4 years 9 months	48.55	48.91	49.10	49.41	49.97	50.65	51.40	52.15	52.65	52.99	53.67
5 years	48.73	49.08	49.27	49.57	50.12	50.79	51.52	52.26	52.74	53.08	53.75
5.5 years	48.89	49.24	49.43	49.73	50.28	50.93	51.66	52.38	52.85	53.18	53.83
6 years	49.13	49.47	49.66	49.96	50.50	51.15	51.87	52.60	53.08	53.40	54.07
6.5 years	49.30	49.65	49.84	50.15	50.69	51.34	52.06	52.78	53.25	53.56	54.21
7 years	49.44	49.80	50.00	50.31	50.86	51.52	52.24	52.95	53.40	53.70	54.31
7.5 years	49.55	49.92	50.13	50.45	51.02	51.68	52.40	53.09	53.52	53.81	54.39
8 years	49.65	50.03	50.24	50.58	51.15	51.83	52.54	53.22	53.64	53.92	54.47
8.5 years	49.71	50.12	50.34	50.69	51.28	51.96	52.67	53.33	53.74	54.01	54.53
9 years	49.76	50.20	50.43	50.79	51.40	52.10	52.80	53.45	53.84	54.10	54.59
9.5 years	49.82	50.29	50.54	50.92	51.55	52.26	52.96	53.58	53.96	54.20	54.65
10 years	49.90	50.41	50.68	51.08	51.74	52.45	53.14	53.74	54.10	54.33	54.75
10.5 years	50.00	50.55	50.84	51.26	51.94	52.66	53.34	53.92	54.26	54.47	54.87
11 years	50.12	50.71	51.01	51.46	52.16	52.88	53.55	54.12	54.44	54.64	55.02
11.5 years	50.27	50.89	51.21	51.66	52.38	53.10	53.76	54.31	54.63	54.83	55.19
12 years	50.44	51.08	51.40	51.87	52.58	53.31	53.97	54.51	54.82	55.02	55.37
12.5 years	50.62	51.28	51.61	52.08	52.80	53.53	54.18	54.73	55.03	55.23	55.58
13 years	50.83	51.51	51.84	52.32	53.05	53.78	54.43	54.97	55.27	55.46	55.81
13.5 years	51.04	51.74	52.08	52.58	53.32	54.05	54.70	55.23	55.53	55.72	56.06
14 years	51.25	51.98	52.33	52.83	53.58	54.31	54.96	55.49	55.79	55.98	56.31
14.5 years	51.45	52.20	52.55	53.06	53.81	54.55	55.20	55.73	56.03	56.21	56.54
15 years	51.64	52.39	52.74	53.25	54.01	54.75	55.40	55.93	56.23	56.42	56.75
15.5 years	51.82	52.55	52.91	53.41	54.17	54.91	55.57	56.11	56.41	56.6	56.93
16 years	52.00	52.71	53.05	53.55	54.30	55.05	55.71	56.26	56.57	56.76	57.11
16.5 years	52.19	52.87	53.20	53.69	54.43	55.18	55.85	56.41	56.73	56.93	57.29
17 years	52.39	53.04	53.36	53.84	54.57	55.32	56.00	56.57	56.9	57.10	57.47
17.5 years	52.61	53.22	53.53	53.98	54.70	55.44	56.13	56.71	57.04	57.26	57.64
18 years	52.82	53.38	53.67	54.10	54.79	55.52	56.21	56.81	57.15	57.37	57.78
18.5 years	53.02	53.51	53.77	54.17	54.82	55.53	56.22	56.83	57.20	57.43	57.86
19 years	53.18	53.62	53.85	54.20	54.81	55.49	56.18	56.81	57.20	57.44	57.92
19.5 years	53.38	53.76	53.96	54.28	54.84	55.48	56.17	56.82	57.22	57.49	58.02

Table 4. The characteristics of families and children involved in the research.

Characteristics		Frequency	Percent
Microcephaly in the close relatives	Yes	347	6.15
	No	5294	93.85
	Total	5641	100
Macrocephaly in the close relatives	Yes	116	2.06
	No	5525	97.94
	Total	5641	100
Income	0-1000	1450	25.7
	1001-1500	2093	37.1
	1501-2000	1204	21.34
	2001-2500	384	6.81
	2501-3000	157	2.78
	3001-3500	81	1.44
	3501-4000	132	2.34
	4001+	140	2.48
	Total	5641	100
Education level of mother	Not to attend school	139	2.46
	Primary school	3101	54.97
	Middle school	1305	23.13
	High school	741	13.14
	University	355	6.29
	Total	5641	100
Education level of father	Not to attend school	15	0.27
	Primary school	2308	40.91
	Middle school	1056	18.72
	High school	1311	23.24
	University	951	16.86
	Total	5641	100
Child's school success	Not to attend school	2639	46.78
	Failure	131	2.32
	Pass	432	7.66
	Successful	938	16.63
	Certificate of appreciation	878	15.56
	Certificate of high achievement	623	11.04
	Total	5641	100
Smoking during pregnancy*	Yes	627	57.79
	No	458	42.21
	Total	1085	100
Smoking after childbirth*	Yes	621	57.24
	No	464	42.76
	Total	1085	100
Form of nutrition*	Breast milk	423	39.87
	Supplementary food	201	18.94
	Mixed	403	37.98
	Formula feeding	34	3.2
	Total	1061	100

*: for children under 24 months

Table 5. Statistical results of concerning factors that may affect head size

Partial correlations independent from age effect				
	Boys		Girls	
	r	p	r	p
Whether there is someone with small head in the family	-0.0112	0.53	-0.0265	0.17
Whether there is someone with large head in the family	0.004	0.76	0.0158	0.38
Socio-economic condition of the family	0.0279	0.12	0.019	0.32
The mother's educational status	0.0149	0.41	-0.0304	0.12
The father's educational status	0.0195	0.287	-0.011	0.55
The child's performance at school	0.13	0	-0.0042	0.87
Baby's birth weight	**0.3335**	**0**	**0.3933**	**0**
Smoking during pregnancy	0.1095	0.008	0.065	0.15
Smoking after giving birth	0.1093	0.008	0.063	0.16

Table 7: Results of the studies conducted worldwide by 50% head circumference values of boys of various ages

Age	Studies						
	Ours	WHO (2006)	Werner (2006)	Mouzan (2007)*	Roelants (2009)	Rollins (2010)	Schienkiewitz (2011)*
			Sweden	S.Arabia	Belgium	USA	Germany
0 months	35.37	34.50	35.00	34.60	34.80	35.81	
3 months	40.04	40.50	41.00.	40.20	40.90	41.77	41.90
6 months	43.15	43.30	44.00	43.40	43.90	44.04	44.20
9 months	44.93	45.00	46.50	45.00	45.60	45.48	45.80
1 2 months	46.07	46.10	47.50	46.20	46.80	46.50	46.20
1 5 months	46.94	46.80	48.50	47.00		47.26	47.20
1 8 months	47.37	47.40	49.20	47.60	48.20	47.86	48.20
2 1 months	48.13	47.80		48.00			49.00
2 4 months	48.43	48.30	50.20	48.20	49.10	49.37	49.60
3 years old	49.79	49.50	51.00	49.30	50.20	50.41	50.20
6 years old	51.43	50.70		50.90	51.70	51.89	52.10
9 years old	52.47			52.10	52.80	53.12	53.30
12 years old	53.58			53.20	54.00	54.29	54.60
15 years old	54.72			54.50	55.70	55.43	55.80
18 years old	55.88			55.60	56.50	56.40	56.80

* Results were obtained from the curves.
WHO: World Health Organization

Table 6. Head circumference values of 7 days old and younger according to cigarette exposure in the intrauterine period

	Boys			Girls		
Smoking during pregnancy	**n**	**Mean (cm)**	**sd**	**n**	**mean**	**sd**
Yes	39	34.5384	.7572	38	34.2947	.8190
No	29	34.7344	.9355	24	34.6208	1.8091
Total	68	34.6220	.8369	62	34.4209	1.2909

Table 8: Results of the studies conducted worldwide by 50% head circumference values of girls of various ages

Age	Studies						
	Ours	WHO (2006)	Werner (2006)	Mouzan (2007)*	Roelants (2009)	Rollins (2010)	Schienkiewitz (2011)*
			Sweden	S.Arabia	Belgium	USA	Germany
0 months	34.85	33.90	35.00	34.30	34.30	34.71	
3 months	39.18	39.50	40.00	39.50	39.70	40.47	40.40
6 months	42.10	42.20	43.00	42.50	42.70	42.71	42.50
9 months	43.89	43.80	45.00	44.20	44.40	44.16	44.40
12 months	45.10	44.90	46.30	45.40	45.60	45.20	45.00
15 months	45.94	45.70	47.00	46.20		45.98	46.00
18 months	46.34	46.20	48.00	46.90	47.00	46.59	46.80
21 months	47.17	46.70		47.20			47.20
24 months	47.50	47.20	49.00	47.70	48.00	48.38	48.00
3 years old	49.00	48.50	50.00	48.50	49.20	49.50	49.00
6 years old	51.15	51.80		50.40	50.70	51.19	51.10
9 years old	52.10			51.80	52.20	52.31	52.10
12 years old	53.30			53.50	53.70	53.31	53.50
15 years old	54.74			54.40	54.70	54.10	54.60
18 years old	55.52			54.50	54.90	54.56	55.20

*: Results were obtained from the curves.
WHO: World Health Organization

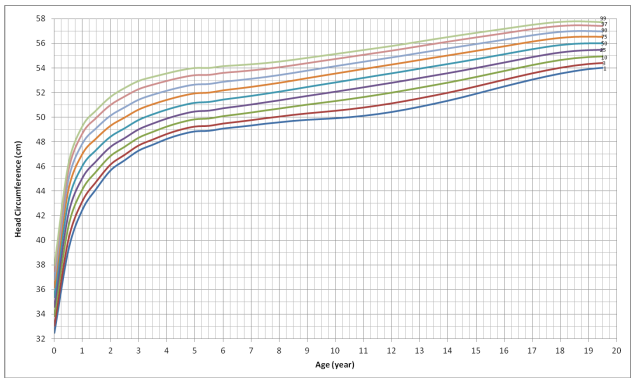

Figure 3: The head circumference curves limited to 1-99% for boys of all ages

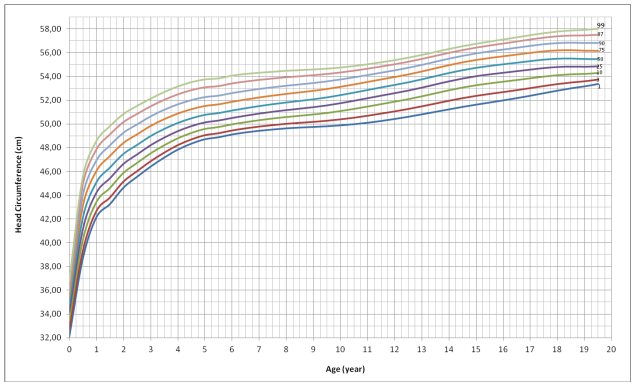

Figure 4: The head circumference curves limited to 1-99% for girls of all ages

Discussion

Growth curves are tools providing valuable information to pediatricians on distinguishing sick children from healthy children, identifying children with growth problems, and showing how healthy children should grow (10).

Growth characteristics of children from different countries, even from different regions of the same country, can be different from each other. Therefore, it was reported that every country should use growth curves estimated using values of their own children (11). It was suggested that growth curves should be renewed at regular intervals because children's growth characteristics also vary between generations (1). In a retrospective cohort study of 75.412 children in a primary care network, the proportion of children with HC >95th percentile was 8.6 percent with the CDC curve and 14 percent with the WHO curve. The proportion of subjects with OFC <5th percentile was 2.9 percent using the CDC curves and 2.3 percent using the WHO curve (12). The differences between national or ethnic group head circumference means were large enough that using the WHO charts would put many children at risk for misdiagnosis of macrocephaly or microcephaly. The findings indicate that the use of a single international standard for head circumference is not justified (4).

HC is an indicator of brain volume and cognitive functions in children (13). In a retrospective childhood study, von der Hagen et al. reported that microcephaly was associated with intellectual impairment in 65% of participants, epilepsy was diagnosed in 43%, and ophthalmological disorders were found in 30% (14). The follow-up of HC is very important in terms of assessment and monitoring of children's development. HC growth curves are also of importance in terms of detection of diseases characterized by having a large head or small head (15).

It was suggested that parents' education level affects their children's growth and development, and that especially well trained mothers contribute better to the growth of their children (16). The reasons for this can be that the well-educated mothers feed their children more consciously, provide more appropriate environment for development of their children and ensure that necessary treatment is provided to their children in a timely and more accurate manner. However, according to the education level of the mother or father HC does not show significant difference. Similarly, it was observed that the HC of the girls did not show a statistically significant difference according to the performance level of the child in the school, but showed a significant difference for boys. As the school performance increases, the HC measurement of boys grows by an average of 0.115 cm. In a study, it was stated that school performance declines in the event that HC differs by more than 2 standard deviations (17).

Chronic diseases in children may adversely affect growth (18-20). If such types of diseases of children are kept under control, the children's growth values become much better; however, they still remain below the values of their peers (21, 22). Similarly, continuous use of drugs can adversely affect the growth of children (23, 24). Therefore, we excluded the children with chronic diseases or those on medication from our study.

Since our aim in this study was to obtain HC curves by making measurements on healthy children, preterm babies, those born after multiple pregnancy and low birth weight babies were not included in the study. One of the important results of the study is that birth weight has a significant effect on HC for both boys and girls who are younger than 2 years.

Home smoking was questioned for children less than 2 years of age to assess whether the smoking had an adverse effect on the measurement of the head circumference of the child. No smoking during pregnancy period and no smoking after birth were found to cause reduction in the HC measurement of boys. No significant difference was observed for girls.

This result can be considered as quite surprising. Because the inhibiting effect of smoking on growth is commonly known. However, it is possible to come across reports with different results in this regard. De

Brito et al. reported that intrauterine growth restriction had major impact on the growth trajectory of the infants, regardless of other factors, such as smoking and diet (25). A study, in Japan showed that the individual effects of maternal smoking were related to low birth weight, short birth length and small head circumference. The individual effects of paternal smoking were related to short birth length and small head circumference. But in the adjusted model, both parents' smoking showed only clear associations with low birth weight and short birth length (26). Is our smoking detection method safe? Shisler et al. assessed prenatal tobacco exposure (PTE) by four methods: a single item question, a calendar-based self-report measure from each trimester of pregnancy, maternal salivary cotinine assays, and nicotine and metabolites in infant meconium. Results suggest that we may be greatly underestimating the negative effects of prenatal smoking on fetal growth and other important child outcomes if we rely solely on restricted single item self-report measures of prenatal smoking. The authors concluded that researchers should consider more intensive prospective self-report measures and biological assays as viable and superior alternatives to single item self-report measures (27). We assessed tobacco exposure by a single item question. So the reliability of our smoking results may be low.

No significant relationship could be shown between presence of people with large or small HC in the family and HC of the child. These results suggest that HC is probably affected by not only the inheritance but also by other causes.

Most of the previous studies on head circumference in Türkiye were made among fewer children and more limited age group (15, 28-30). The Neyzi's work is the largest sample sized of these studies (31). Measured children were from good socio-economic situation, measurements were made at different times by different people. Additionally, HC was measured with tape placed in the horizontal plane encompassing the midpoint of the forehead between the eyebrows and hairline and the occipital prominence. Their total sample consisted of a mixture of children followed longitudinally over different periods of time. In this study, all measurements were performed by the same person using a same set tape whose reliability was confirmed in a calibration laboratory. The accuracy of the measurements repeatability was validated by a preliminary study. Measured children were from all socioeconomic layers of society. Among the repeated measurements the largest one was considered as head circumference. Our work was done in a shorter period and more recently. These particulars are main differences between two studies.

A comparison 50% value of our results with the results of other national studies is given in Tables 7-8. When the results of studies carried out in foreign countries are examined regardless of method differences, the following points are notable: The results of50% percentile of HC in boys less than six years old from World Health Organization and Saudi Arabia are almost the same as our results (32, 33). The largest difference was found with Sweden for all ages (34-38).

Conclusion

In conclusion, HC is a reliable marker of growth and neurological status. We think that our HC results can be utilized in pediatric practice. The following characteristics of the study support this view. The study has been conducted with a remarkable large sample size from all socioeconomic layers of society as so a satisfactory representatives. The HC measurements were performed in children who met special health condition. All measurements were made by the same person. We think all these aspects are the main features of our work and make the work reliable. The current study offers recent and gender-specific HC norms.

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