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Head Circumference for Growth Curves and Percentiles for 0-2-Year-Old Children in Ankara: Comparison with GAMLSS and Quantile Regression Methods

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What is already known on this topic?

- *The most commonly used method for constructing growth curves, as in the WHO reference standards, is the GAMLSS model. However, considering the distribution of the data, the QR method is also an alternative method for constructing growth curves.*

What this study adds on this topic?

- *This study adds current HC growth references and growth curves including the Ankara sample. At the same time, growth percentiles were compared with the Neyzi et al study, which represent the Turkish population and WHO standards. Since the QR method is not commonly used in growth curve studies in Türkiye, it will bring innovation to those who will work on this subject.*

ABSTRACT

Objective: Growth curves are important tools for assessing the growth and development of children in the target population by age. Measuring head circumference (HC) in infants is an important tool in monitoring infant health and brain development. The aims of this study are to construct current 0-2-year-old HC growth curves and percentiles and compare the methods used in the construction of growth curves for HC measurements by gender.

Materials and Methods: The study is a retrospective research that includes the HC measurements of a total of 2832 (n = 1438 girls, n = 1394 boys) children examined between 2018 and 2021 in Başkent University hospital, Ankara. Lambda-Mu-Sigma, LMSP, and LMST methods based on Box-Cox Cole and Green (BCCG), Box-Cox power exponential (BCPE), and Box-Cox *t* (BCT) distributions respectively, and quantile regression (QR) method were used to construct the fitted growth curves. Model performances were evaluated using the generalized Akaike information criterion. The analyses were conducted using R 4.1.2 version.

Results: According to the LMS and QR methods, percentile values of HC measurements by gender were calculated and the results were compared. Smoothed HC growth curves were constructed and compared for both methods by gender. The present study, Neyzi et al study, and World Health Organization (WHO) standards were compared for the third, 50th and 97th percentiles of HC.

Conclusion: This study showed that the third-97th HC percentiles calculated by LMS and QR methods are very close to each other. Additionally, this study showed that the HC percentiles of Turkish children were slightly different compared to WHO standards.

Keywords: BCCG–BCPE–BCT distributions, growth curve, head circumference, LMS–LMSP–LMST methods, quantile regression

INTRODUCTION

Growth monitoring is an integral part of good child care. Atypical growth patterns may indicate medical, nutritional, or developmental problems.[1] Growth monitoring may be more important in developing countries where growth retardation owing to insufficient nutrition and/or infections is common.[2] Growth curves are the best indicators to summarize changes in the children's general health beginning from birth. With the help of these curves, the extent to which physiological needs are met in the growth and development of a child in a society, monitoring the nutritional status, and early diagnosis of disease are evaluated.[3]

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Head circumference (HC) at birth is an important indicator of brain development, and cognitive functions are related to brain volume according to age and gender. Brain development in children is monitored by measuring HC from birth onwards.[4,5]

Measuring HC is a rapid, non-invasive method of determining whether an infant's head is too large (megacephaly) or too small (microcephaly).[6] When compared to standard growth curves, regular HC measurements are crucial for tracking an infant's health. The procedure is considered "the simplest, cheapest, and fastest available [tool] for assessing central nervous system development and identifying newborns at risk of neurodevelopmental disorders."[7] Head circumference is also often measured in at-risk infants (e.g., preterm or low-birth-weight infants or those with known genetic disorders); most clinicians include serial HC measurements in routine well-baby visits or as part of the regular care of infants and children admitted to the hospital for reasons other than growth concerns (i.e., opportunistic growth measurements).[8]

Growth standards have long been of interest to many researchers. The earliest known study on growth is that Count Philibert Gueneau de Montbeillard recorded his son's height by measuring him every 6 months from birth to the age of 18 from 1759 to 1777.[9] In 1946-1954, English children's height and weight standards for age were generated.[10] Growth standards for American children from birth to age 18 were constructed by the National Center for Health Statistics, and Dutch children's growth standards were published in 1985 by Roede and Van Wieringen.[11,12] For Turkish population, Neyzi conducted many studies on growth standards among Turkish children.[13] In addition, percentile values and growth curves for current height, weight, and body mass index (BMI) measurements between the ages of 0 and 24 months were constructed by Çakmak et al.[14] Head circumference growth reference charts for children aged 0-84 months were constructed in Kayseri province, Türkiye.[15] Also, Multicentre Growth Reference Study is currently being conducted by the World Health Organization (WHO) to monitor the growth and development of children. With these multi-center studies, new growth references are being developed for countries. In this way, children's growth norm references regarding new approaches to health, nutrition, and other conditions specific to societies are formed.[16] With the help of anthropometric measurements, reference percentile curves representing the whole society according to gender are constructed for each age. Also, with the help of reference growth curves, it is possible to evaluate whether a child is within age and gender-specific normal ranges and whether his or her trend of development is normal.

Height-for-age, weight-for-age, head circumference-for-age, and BMI-for-age are the most commonly used anthropometric measurements among growth curves. Since these measurements generally do not show a normal distribution, the data are approximated to the normal distribution with the help of an appropriate power transformation. For this purpose, Cole developed the Lambda-Mu-Sigma (LMS) method to obtain smoothed reference curves based on the Box-Cox power transformation.[17,18] While modeling only the skewness of the distribution with the LMS method, LMSP and LMST methods were developed by Rigby and Stasinopoulos for modeling the distribution by taking into consideration the skewness and kurtosis (platykurtosis and leptokurtosis) of the distribution.[19,20] Another method used to construct growth curves is quantile regression (QR). The QR method was developed by Koenker and Bassett and used by Wei to estimate reference growth curves. The QR method does not require any distribution assumptions in the anthropometric measurement. It is stated that the QR method is a flexible approach, especially when the measurements of children vary depending on age and in the presence of outliers.[21,22]

The aims of this study is to construct current HC percentiles, compare the different methods used in the construction of growth curves, and to give reference percentiles of HC measurements according to gender. In addition, the current HC measurements calculated in our study were compared with the HC percentiles in WHO standards and Neyzi et al studies.

MATERIALS AND METHODS

Study Design and Population

Children who were examined in the Pediatrics Clinic of Başkent University Ankara Hospital between January 2018 and December 2021 were included in this study. This is a retrospective study and consists of HC measurements of 1438 girls and 1394 boys.

All children included in the study were healthy and breastfeeding, single-term births, and had no genetic disorders or chronic diseases. This study was approved by the Ethics Committee of Hacettepe University (approval number: GO 20/757, date: 23.06.2020). The study was conducted in accordance with the principles of the Helsinki Declaration.

During each visit, parents are asked to provide detailed information about the infant's feeding routine, parent–child interactions, the baby's development, and any new health issues or concerns since the last visit. A thorough physical exam, including anthropometric measurements, is conducted each time. All data on the infants/children attending the Clinic are recorded in the hospital database. Pediatricians measure HC using a narrow, non-stretch tape positioned horizontally around the forehead's midpoint, between the eyebrows and hairline, and extending to the occipital prominence. These measurements are then recorded in the health information system. The HC measurements of the children in this study are taken by the same pediatrician with the same tape while infants are lying on examination bed. The measurement of HC is taken by the same person with the same tape twice, and the mean was used for analysis.

The HC measurement is plotted on an age- and sex-appropriate growth chart to determine its percentile. If HC is more than 2 SD below the mean (approximately third centile) and similar to height and weight, it is defined as proportional microcephaly; if length and weight are well above the third centile but HC is at or below, then the term disproportionate microcephaly is used.[23]

When constructing growth curves, the age range should be as narrow as possible in age groups where growth is rapid. It is stated that it is sufficient to have at least 100 samples for each range.[17] The age grouping of children was classified as monthly for the first 6 months, at intervals of 3 months from the 9th to 18th months, and then at 6 months from the 24th month onward.

Statistical Analysis

LMS–LMSP–LMST Methods

Since measurements such as height, weight, and HC show a skewed distribution, power transformation is required to ensure normality. The Lambda-Mu-Sigma (LMS) method provides normality in the distribution by removing the skewness in the data with the help of the Box-Cox power transformation. As stated in the name of the LMS method, it is summarized in the form of 3 curves: the L curve (λ, power transformation), the M curve corresponding to the 50th percentile (μ, median), and S curve (σ, coefficient of variation). The LMS method is based on the Box-Cox Cole and Green (BCCG) distribution.[17]

Z-score and percentile values are used in the evaluation and interpretation of pediatric growth curves. Measurement values are converted to a *Z*-score with a mean of 0 and an standard deviation (SD) of 1. The *Z*-score is calculated by subtracting the mean from the measurement values and dividing the difference by the SD. The mean and SD values of the reference population are calculated from the data. The *Z*-score calculated according to the LMS method is explained in equations (2.1) and (2.2) below. Each *Z*-score has a percentile equivalent, for example, −2 < *Z*-score < +2 corresponds to 2.3rd–97.7th percentile range. Although the use of percentile values in the clinical evaluation of growth, development, and nutritional status of children is common and practical, the *Z*-score can also be interpreted for any specific measurement values.[24]

Equation (2.1) is obtained by substituting $L(t)$, $M(t)$, and $S(t)$ respectively for λ, μ, and σ values. The y value indicates an anthropometric measurement. Percentile calculation for the measurement y at t (age) is given in Equation (2.2).[18]

$$Z = \begin{cases} \dfrac{\left[y / M(t) \right]^{L(t)} - 1}{L(t)S(t)}, L(t) \neq 0 \\ \dfrac{\log\left[y / M(t) \right]}{S(t)}, L(t) = 0 \end{cases} \quad (2.1)$$

$$C_{100\alpha} = \begin{cases} M(t)\left(1 + L(t)S(t)z_\alpha\right)^{\frac{1}{L(t)}}, L(t) \neq 0 \\ M(t)e^{S(t)z_\alpha}, L(t) = 0 \end{cases} \quad (2.2)$$

The LMS method does not consider the kurtosis of the distribution while modeling its skewness. In this case, the Generalized Additive Model for Location, Scale, and Shape (GAMLSS) model was developed for modeling Box-Cox Power Exponential (BCPE) and Box-Cox *t* (BCT) distributions in cases where the distribution of the anthropometric measurement is both skewed and kurtotic. The LMSP and LMST methods are based on the BCPE and BCT distributions.[19]

Box-Cox power exponential (x = age$^{\lambda}$, df_μ, df_σ, df_υ, df_τ) model shows the power transformation at age for the first parameter λ, and the last 4 parameters μ, σ, υ, τ are the equivalent degrees of freedom (edf). In our study, to evaluate the model performances, we used these notations. The parameters of the BCT (μ, σ, υ, τ) distribution are similar to the BCPE model. Box-Cox *t* distribution can model high leptokurtosis.Box-Cox Cole and Green, BCPE, and BCT models are called the GAMLSS model.

Quantile Regression

Quantile Regression is a nonparametric method and does not require an assumption about the normality of the data. The QR method allows estimation of conditional quantile curves. The QR method solves the problem of extremes/outliers and performs parameter estimation for data in different parts of the distribution. Each quantile curve is denoted by τ (0 < τ < 1). *P* is the degree of smoothing of the function. The τth regression quantile ($\hat{\beta}(\tau)$) estimation is shown in Equation (2.3).[22]

$$\hat{\beta}(\tau) = argmin_{\beta \in R^p} \left\{ \sum_{i=1}^{n} \rho_\tau \left(y_i - x_i^{'}\beta \right) \right\} \quad (2.3)$$

Software

The analyses were conducted using *R* version 4.1.2 (Company; City, Country). The "*gamlss*" package version 5.4-1 version (Company; City, Country) was used to construct growth curves and evaluate model performances in the BCCG, BCPE, and BCT methods.[25] "*quantregGrowth*" package version 1.4-0 version was also used in the QR method.[26,27]

Model Design and Selection

Maximum penalized likelihood method was used to estimate the distribution parameters BCCG, BCPE, and BCT. Cubic splines were used as the function for smoothing the curves. Generalized Akaike information criterion (GAIC) was used to evaluate model performances for BCCG, BCPE, and BCT, therefore penalty was determined as #=3.

To begin with, we performed power transformation between −1 and +1 using a grid search approach with 0.25 steps over the age. Thus, λ (age-transformation power) was determined for the smallest global deviance. The model started with a value of 1 edf for all parameters (μ, σ, υ, τ). We then set the model parameters as combinations of $df\mu$ ranging from 5 to 15, $df\sigma$ ranging from 2 to 10, df_υ ranging from 0 to 9, and df_τ ranging from 0 to 4 to determine the edf of the parameters with the smallest GAIC (#=3). Model parameters were selected with the *find.hyper*() function with the help of an automatic procedure in the GAMLSS package.

In constructing the quantile curves, the most optimal λ smoothing parameter was selected through cross-validation in the *ps()* function in the "*quantregGrowth*" package. At the same time, with the *gcrq()* function, the non-crossing problem in the quantiles (the range of 0.03–0.97) was eliminated by the B-spline method with a penalty coefficient. Besides, age-related monotony restrictions were provided.

RESULTS

The mean ± SD of HC measurements and percentile values for HC by the LMS method to gender (third–97th percentile) are given in Table 1.

Table 1. Head Circumference-for-Age Percentiles of Children from 1 to 24 Months with the LMS Method

Months	n	Mean ± SD	L	M	S	3rd	5th	10th	25th	50th	75th	90th	95th	97th
Girls Percentiles (HC in cm)														
1	127	36.86 ± 0.96	0.479	36.854	0.026	35.08	35.30	35.64	36.21	36.85	37.50	38.09	38.45	38.68
2	118	38.75 ± 1.01	3.155	38.774	0.026	36.77	37.03	37.43	38.08	38.77	39.44	40.02	40.36	40.58
3	116	39.68 ± 1.01	−3.293	39.630	0.025	37.94	38.13	38.44	38.99	39.63	40.32	40.99	41.42	41.71
4	127	40.89 ± 1.05	1.890	40.898	0.026	38.85	39.11	39.51	40.18	40.90	41.61	42.24	42.62	42.86
5	115	41.81 ± 1.02	1.983	41.824	0.024	39.89	40.14	40.52	41.14	41.82	42.50	43.09	43.44	43.67
6	133	42.91 ± 1.17	4.429	42.960	0.027	40.56	40.89	41.38	42.15	42.96	43.72	44.37	44.74	44.97
9	140	44.45 ± 1.26	6.041	44.528	0.027	41.91	42.28	42.83	43.68	44.53	45.30	45.95	46.32	46.55
12	126	46.07 ± 1.22	0.079	46.057	0.026	43.86	44.13	44.55	45.26	46.06	46.87	47.62	48.07	48.36
15	139	46.94 ± 1.19	4.385	46.986	0.025	44.58	44.90	45.39	46.17	46.99	47.76	48.42	48.80	49.04
18	129	47.61 ± 1.03	1.221	47.610	0.022	45.63	45.88	46.26	46.90	47.61	48.32	48.95	49.32	49.57
24	168	48.33 ± 1.30	1.324	48.340	0.027	45.86	46.18	46.66	47.46	48.34	49.22	50.00	50.47	50.78
Boys Percentiles (HC in cm)														
1	124	37.84 ± 0.99	2.683	37.857	0.026	35.92	36.18	36.56	37.18	37.86	38.51	39.09	39.42	39.64
2	117	39.99 ± 0.95	−2.142	39.955	0.024	38.27	38.47	38.78	39.33	39.96	40.62	41.25	41.64	41.90
3	118	41.34 ± 0.92	6.010	41.391	0.022	39.47	39.74	40.13	40.75	41.39	41.98	42.48	42.77	42.95
4	124	42.16 ± 1.04	−0.402	42.139	0.025	40.22	40.46	40.82	41.44	42.14	42.86	43.52	43.92	44.19
5	132	43.33 ± 1.16	−3.094	43.271	0.027	41.28	41.51	41.87	42.51	43.27	44.01	44.89	45.39	45.73
6	117	44.30 ± 1.10	0.247	44.288	0.025	42.24	42.50	42.89	43.55	44.29	45.04	45.73	46.14	46.41
9	123	45.89 ± 1.25	1.412	45.898	0.027	43.54	43.84	44.30	45.06	45.90	46.73	47.48	47.92	48.21
12	142	47.06 ± 0.98	−5.253	47.000	0.021	45.34	45.53	45.83	46.36	47.00	47.70	48.38	48.83	49.13
15	138	48.04 ± 1.02	−4.057	47.988	0.021	46.26	46.46	46.78	47.33	47.99	48.69	49.38	49.81	50.10
18	128	48.51 ± 1.21	1.434	48.512	0.025	46.21	46.50	46.95	47.69	48.51	49.33	50.06	50.49	50.77
24	131	49.49 ± 1.24	−0.087	49.474	0.025	47.21	47.48	47.92	48.65	49.47	50.32	51.09	51.56	51.86

Table 2. Model Distribution Parameters for HC by Gender

		Distribution Parameters					
	λ	sd_μ	$sd\sigma$	sd_υ	$sd\tau$	AIC	GAIC (#=3)
Girls							
HC (cm)							
BCPE	0.62	7.1	4.1	2.8	2.1	4359.01	4375.11*
BCT	0.65	7	4.1	3.1	2.1	4359.03	4375.33
BCCG	0.65	7.1	4.1	2.1	–	4372.41	4385.71
Boys							
HC (cm)							
BCPE	0.15	5.7	5.3	2.1	2.1	4167.54	4182.74
BCT	0.10	5.7	5.2	2.1	2.1	4167.26	4182.36
BCCG	0.45	5.9	4	2.1	–	4167.62	4179.65*

*The most optimal model.

Model performances were examined according to distribution parameters and given in Table 2. The model chosen for HC of the girls was BCPE ($x = age^{\lambda=0.62}$, $df\mu = 7.1$, $df\sigma = 4.1$, $df_\upsilon = 2.8$, $df_\tau = 2.1$), and the model performances were calculated as AIC = 4359.01, GAIC(#=3) = 4375.11. The model chosen for HC of the boys was BCCG ($x = age^{\lambda=0.45}$, $df_\mu = 5.9$, $df_\sigma = 4$, $df_\upsilon = 2.1$), and the model performances were calculated as AIC = 4167.62, GAIC(#=3) = 4179.65. Head circumference-for-age fitted growth curves of the girls and boys are shown in Figure 1.

Quantile values for HC by the QR method according to gender (0.03rd-0.97th quantile) are given in Table 3, and QR growth curves are given in Figure 2. Comparisons of smoothed growth curves constructed according to the GAMLSS model and QR method are given in Figure 3.

Z-scores for head circumference in the range of (−3, +3) SD according to gender are given in Table 4.

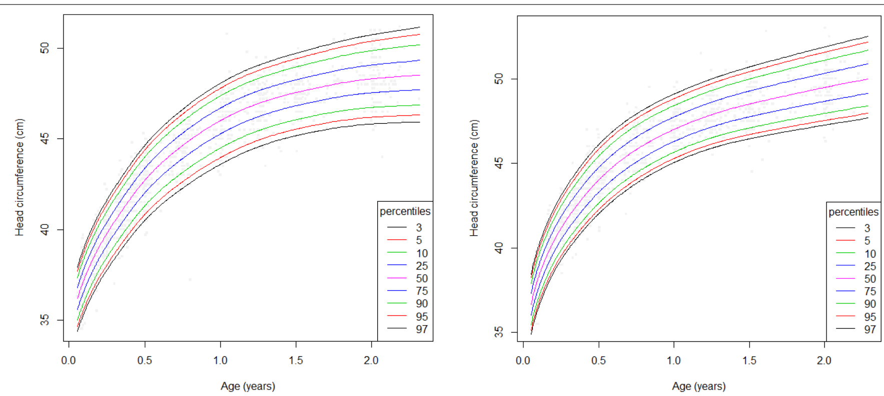

Figure 1. Head circumference-for-age growth curves of girls (left) and boys (right) with GAMLSS model.

Table 3. Head Circumference-for-Age Quantiles of the Children from 1 to 24 Months Using the QR Method

Girls Quantiles (τ) (HC in cm)										
Months	**n**	**0.03**	**0.05**	**0.10**	**0.25**	**0.50**	**0.75**	**0.90**	**0.95**	**0.97**
1	127	35.05	35.24	35.54	35.93	36.64	37.19	37.63	38.07	38.40
2	118	36.49	36.72	37.10	37.60	38.34	38.90	39.46	39.95	40.33
3	116	37.54	37.81	38.23	38.81	39.57	40.14	40.77	41.26	41.63
4	127	38.52	38.82	39.26	39.91	40.68	41.27	41.94	42.39	42.73
5	115	39.63	39.95	40.41	41.13	41.91	42.51	43.22	43.57	43.85
6	133	40.52	40.86	41.31	42.08	42.85	43.47	44.19	44.45	44.67
9	140	42.27	42.61	43.01	43.85	44.57	45.25	45.90	46.09	46.33
12	126	43.74	44.13	44.61	45.38	46.16	46.85	47.47	47.75	48.05
15	139	44.50	44.92	45.47	46.18	46.97	47.63	48.30	48.72	48.99
18	129	45.44	45.90	46.40	47.10	47.77	48.53	49.36	49.97	50.16
24	168	45.99	46.47	46.79	47.57	48.20	49.05	50.12	50.79	50.93
Boys Quantiles (τ) (HC in cm)										
1	124	36.06	36.31	36.63	37.11	37.72	38.35	38.72	39.05	39.24
2	117	37.53	37.84	38.24	38.84	39.54	40.22	40.70	41.09	41.32
3	118	38.63	38.97	39.41	40.08	40.84	41.55	42.09	42.53	42.78
4	124	39.65	40.01	40.49	41.21	41.99	42.74	43.33	43.79	44.08
5	132	40.82	41.20	41.70	42.45	43.23	44.01	44.65	45.13	45.46
6	117	41.78	42.16	42.66	43.40	44.16	44.95	45.62	46.10	46.47
9	123	43.73	44.04	44.48	45.12	45.74	46.55	47.22	47.66	48.09
12	142	45.49	45.63	45.88	46.47	47.08	47.86	48.51	48.85	49.16
15	138	46.18	46.34	46.56	47.16	47.85	48.61	49.24	49.56	49.77
18	128	46.89	47.17	47.41	48.02	48.85	49.65	50.25	50.71	50.80
24	131	47.29	47.64	47.88	48.50	49.50	50.42	51.00	51.81	51.88

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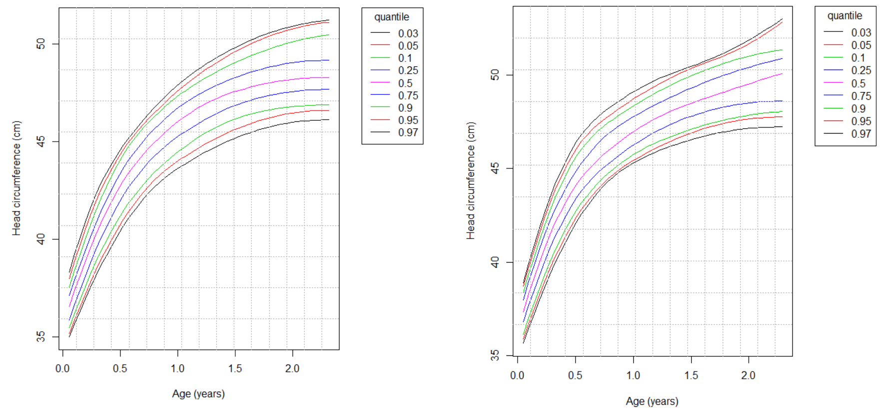

Figure 2. Head circumference-for-age growth curves of girls (left) and boys (right) with QR method.

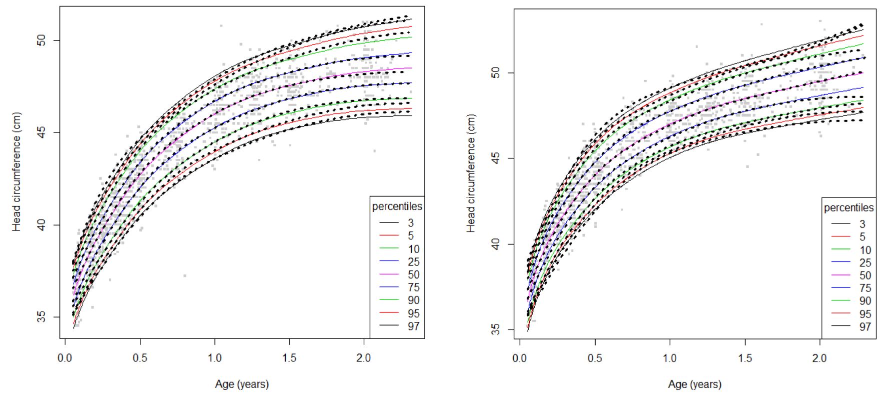

Figure 3. Comparison of head circumference-for-age growth curves of girls (left) and boys (right) with GAMLSS model and QR method. Note: Black dashed lines smoothed are quantile curves.

The present study, the Neyzi et al[13] study, and the WHO standards[16] were compared for the third, 50th and 97th percentiles of HC according to gender in Figure 4.

DISCUSSION

Constructing reference growth curves requires complicated statistical methods. The most commonly used method for the construction of pediatric growth curves is the GAMLSS model. However, in the case that the normal distribution assumption is not satisfied by the data, the QR method, which is developed as an alternative, can also be used to construct the growth curves. In our study, percentile values of HC percentiles according to gender were calculated by the LMS method and QR method. Model performances of these anthropometric measurements were compared using LMS, LMSP and LMST methods. Among these 3 methods, the method providing the best fit to the data was determined, and smoothed growth curves were constructed. We compared the growth curves constructed by the GAMLSS model and QR method.

When the percentiles of girls' HC were examined, it was seen that the 50th percentile values of our study and the Neyzi et al[13] study were quite similar in all months. Only in the Neyzi et al[13] study, 4th and 5th month HC measurements are not available. When compared with WHO standards,[15] while the first 6 months are very similar to the percentile values in our study, they differ by approximately 1 cm by the 9th month. When the 50th percentile values of the HC of the boys in our study and the Neyzi et al[13] study were compared, it was observed that the values were quite close to each other. However, when HC percentile values of Turkish children were compared with WHO standards,[16] it was observed that they varied between 0.54 cm and 0.99 cm for the first 12 months. It was observed that the percentile values after the 15th month varied by 1 cm.

When the percentile values third-97th calculated according to the LMS and QR methods were examined, it was observed that the results were quite close to each other. This shows us that both methods give consistent and reliable results. However, there are important points that need to be taken into consideration when constructing growth curves with these 2 methods. In the construction of the growth curves, attention should be given to ensuring flexibility, non-crossing, and monotony in the curves. While obtaining non-crossing curves in GAMLSS models is realized with the help of functions in the software algorithm, extra processing is required to obtain non-crossing curves in the QR method. When we examine the growth curves of HC measurements obtained in GAMLSS models, it is seen that there is no crossing between the percentile curves and they are flexible. While it can be said that flexibility and non-crossing are provided for each quantile curve in the QR method, it is seen that there is a tendency to increase monotony with age for the 0.95th and 0.97th quantile curves in the HC of boys.

Table 4. Head Circumference-for-Age *Z*-Scores According to the Gender

Girls' *Z*-scores (HC in cm)							
Months	**−3 SD**	**−2 SD**	**−1 SD**	**Median**	**1 SD**	**2 SD**	**3 SD**
1	34.038	34.964	35.902	36.854	37.819	38.796	39.787
2	35.453	36.633	37.736	38.774	39.755	40.687	41.574
3	37.061	37.837	38.689	39.630	40.678	41.855	43.195
4	37.588	38.720	39.822	40.898	41.949	42.978	43.985
5	38.698	39.767	40.808	41.824	42.816	43.786	44.736
6	38.859	40.389	41.742	42.960	44.070	45.091	46.039
9	39.840	41.711	43.235	44.528	45.656	46.658	47.563
12	42.591	43.719	44.874	46.057	47.269	48.510	49.781
15	42.901	44.407	45.758	46.986	48.114	49.159	50.134
18	44.444	45.505	46.560	47.610	48.655	49.695	50.730
24	44.371	45.706	47.029	48.340	49.640	50.928	52.206
Boys' *Z*-scores (HC in cm)							
1	34.685	35.795	36.850	37.857	38.821	39.745	40.635
2	37.367	38.171	39.031	39.955	40.952	42.031	43.205
3	38.053	39.329	40.426	41.391	42.255	43.039	43.757
4	39.138	40.104	41.104	42.139	43.211	44.322	45.473
5	40.254	41.163	42.163	43.271	44.508	45.905	47.500
6	41.059	42.115	43.191	44.288	45.406	46.544	47.705
9	42.115	43.391	44.652	45.898	47.130	48.350	49.557
12	44.510	45.250	46.073	47.000	48.058	49.284	50.737
15	45.370	46.163	47.031	47.988	49.053	50.249	51.609
18	44.811	46.059	47.293	48.512	49.718	50.912	52.094
24	45.910	47.066	48.254	49.474	50.728	52.016	53.340

Study Limitations

The limitation of this study is that it constructed HC percentile values that included only the Ankara sample. It will be important to construct Türkiye's growth references through multi-center studies.

CONCLUSION

Consequently, it is crucial to determine the type of distribution and the effective degrees of freedom to ensure smoothing in the construction of growth curves. Lambda-Mu-Sigma,

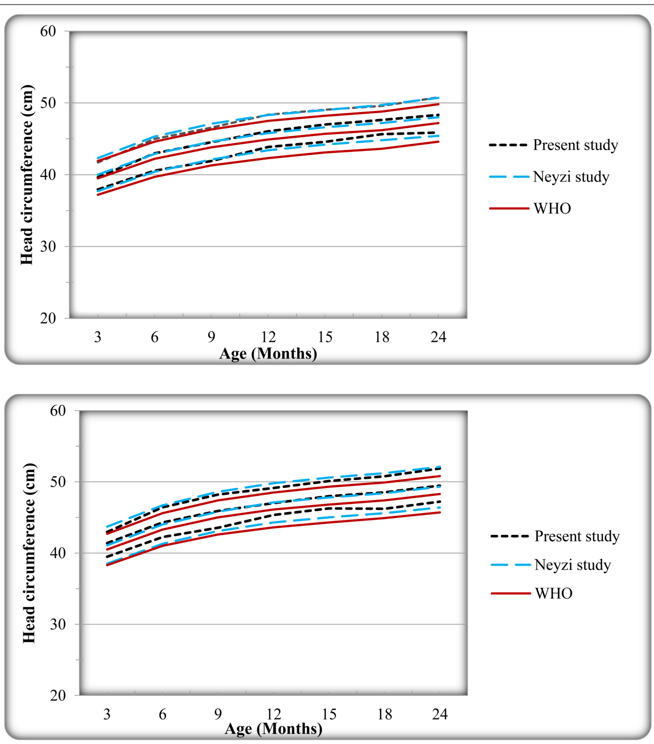

Figure 4. Comparison of thirdd, 50th, and 97th percentiles for HC of girls (top) and boys (bottom) among the present study, the Neyzi study, and the WHO by gender.

LMSP, and LMST methods offer ease of application in terms of determining the transformation parameter on age and effective degrees of freedom with the help of functions. Quantile regression is an alternative method to be used in the construction of growth curves when attention is given to the selection of the smoothing parameters and the problem of non-crossing in the curves. With our study, current percentile values were constructed for 0-24 months' HC measurements. It has also been observed that the HC percentiles of Turkish children are slightly different compared to WHO standards. Our study will be a reference for future studies on the assessment of growth.

Availability of Data and Materials: The data that support the findings of this study are available on request from the corresponding author.

Ethics Committee Approval: This study was approved by the Ethics Committee of Hacettepe University (approval number: GO 20/757, date: 23.06.2020).

Informed Consent: Due to the retrospective nature of the study, informed consent was not obtained.

Peer-review: Externally peer-reviewed.

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