Application of Nonparametric Quantile Regression for Fitting Height-for-age Curves

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Abstract

Introduction: Reference curves are useful tools to monitor children's growth status and can promote growth velocity in infants. In this regard, various parametric and semi-parametric methods are frequently used in the last decades. In the present paper, nonparametric quantile regression method is used as apowerful and applicable methodology to estimate height curves and normal values of height-for-age in children aged 0 to 5 years. The results of this study are compared with World Health Organization (WHO) references and semi-parametric LMS method of Cole and Green.

Methods and Materials: As part of a national survey, 70,737 apparently healthy boys and girls aged 0 to 5 years were recruited in July 2004 for 20 days from among those referring to the community clinics for routine health check-ups. Anthropometric measurements were conducted by trained health staff using WHO methodology. To estimate curves and normal values, we applied the nonparametric quantile regression method obtained by local constant kernel estimation of conditional quantile curves.

Results: Studying a population of boys and girls aged 0 to 5 years living in the northeast of Iran, the weight-for-age growth curves were derived. The results were consistent to those obtained by a semi-parametric *LMS* method with the same data. The median values of the children's weight in all the age groups were lower than the corresponding values in WHO reference data. The weight curves of boys were higher than those of girls in all age groups.

Conclusions: The differences between growth patterns of children living in the northeast of Iran versus the international ones are considerable which necessitate applying local and regional growth charts. International normal values may not properly recognize the populations at risk for growth problems in the Iranian children. Quantile regression (QR) which does not require restricted assumptions is a flexible method, which is proposed for estimating reference curves and normal values.

Keywords: Nonparametric quantile regression, growth curves, normal values.

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Introduction

Age and sex specified reference curve is a tool to routinely monitor children's anthropometric data such as height growth. Determining growth pattern in children for some specific percentiles of anthropometric measurements is of significance in health policy. In addition, special attention to height-for-age and weight-for-age has made the two charts essential for children's growth monitoring.

For a random variable H(height), reference curve presents the interval between two pre-specified centiles (e.g. third and 97th) of the distribution of H, $F_H(h)$. In health sciences, abnormality may be suspected if observed height (h) lies below the lower reference limit or above the upper limit. There are several methods to construct child growth curves but Box-Cox power exponential (BCPE), HRY and LMS are probably the most widely applied approaches in practice (1). For example WHO(2003) constructed child growth curves based on the BCPE(2), Cole et al. (1995) fitted summary centile curves to body mass index data by using LMS method and penalized likelihood(3).

Although existence of several methods provide researchers with more options to choose the best based data from,the methods are not easy to use, systematically efficient or robust to outliers(4,5).

Quantile regression is a superseded powerful and applicable method to construct growth curves. In the present study, we designed height-for-age curves, which is an essential component of the children toolkit (6), for children aged 0-5 in Khorasan province in northeast of Iran. We applied nonparametric quantile regression method for estimating conditional quantile curves. This method estimated quantiles as a smooth function of covariates without procrustean distributional assumptions necessary for parametric methods (6).Furthermore, this method is robust to outliers.

Methods and Materials

Koenker and Bassett (1978) proposed a quantile regression method to estimate conditional quantile functions. In their proposed method, quantiles of distribution of a dependent factor were determined as functions of observed covariates. In this method, the sum of the absolute deviations of the error terms is minimized, whereas in the ordinary regression method sum of squared residuals is minimized(7). Quantile regression can be parametric or nonparametric. In general, the parametric type is called quantile regression (QR).

In the parametric type, when covariates X are considered, the linear conditional quantile function, $Q(\tau|X = x) = x'\beta(\tau)$, can be estimated through:

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

for any quantile $\tau \in (0,1)$.

The quantity $\hat{\beta}(\tau)$ is called the τth regression quantile(4, 8).

In the present paper, the nonparametric quantile regression method was used to estimate height curves and normal values. This method was obtained by local constant kernel estimation of conditional quantiles(LCKECQ).To fit proposed nonparametric quantile regression (NQR), the "quantreq" package in the R program was used. Furthermore respects subjective choice method and also Gaussian kernel were applied during analysis to assess smoothing parameter (9).

Results

In our data set of 70,737 individuals, 36,034 (50.9%) are boys and 34,703 (49.1%) are girls. Non-normality distribution of height in the two sex groups ($P < 0.000$) and the existence of some outliers in the data set, suggested proposed and flexible QR method to estimate growth curves and normal values of height for age. Separately potting scatter diagrams of height versus age for the boys and the girls, did not propose any specified pattern. Therefore, we used the nonparametric type of the quantile regression based on LCKECQ.

Since boys and girls have different growth patterns(4), we constructed growth curves separately by sex. Three quantile (5^{th}, 50^{th} and 95^{th}) curves of height for the boys and the girls are shown in figure 1 and 2, respectively.

Some articles have shown that the results of the semi-parametric *LMS* method of Cole and Green are the same as that shown by QR(6, 10, 11). Nonparametric quantile regression (NQR) can have a substantial role for the spontaneous determination of reference curves and values from restricted or unreliable data (6).Therefore, we provided a visual comparison of the 50^{th} percentile curve estimations of height using NQR method in our data set with those obtained by WHO as reference growth curves for boys and girls, separately(see figure 3). There is quite an agreement between the two curves from birth to age 2 but some differences can be observed after age 3, and finally an increase up to age 5 in both sexes.

In order to show the difference between the two growth patterns in the boys and the girls, a comparison of the 50^{th} percentile growth curves estimations of height might be of great interest. Applying the proposed method (NQR) in figure 4, it was revealed that boys' growth curves estimations are higher than those of girls in all age groups. For each quantile, the regression quantiles were computed at each observed age. The results are shown in Table 1.

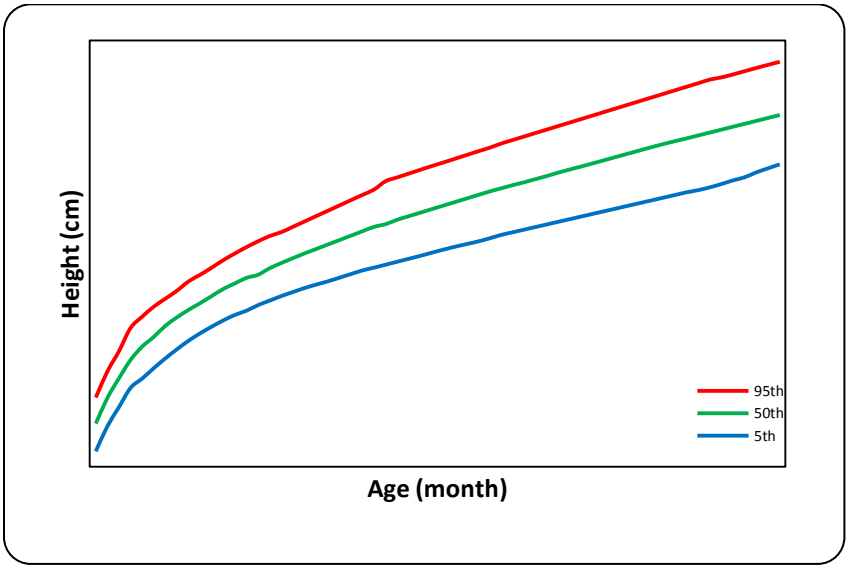


Figure 1: Reference curves in 5^{th}, 50^{th} (median) and 95^{th} percentiles obtained with NQR method using LCKECQ for the northeastern Iranian boys aged 0-5 years

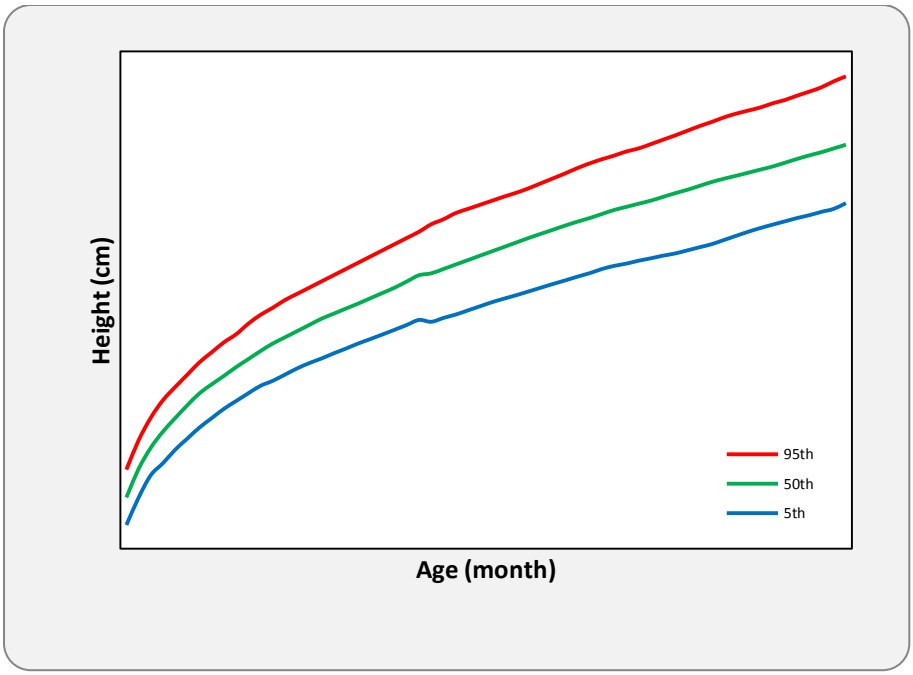
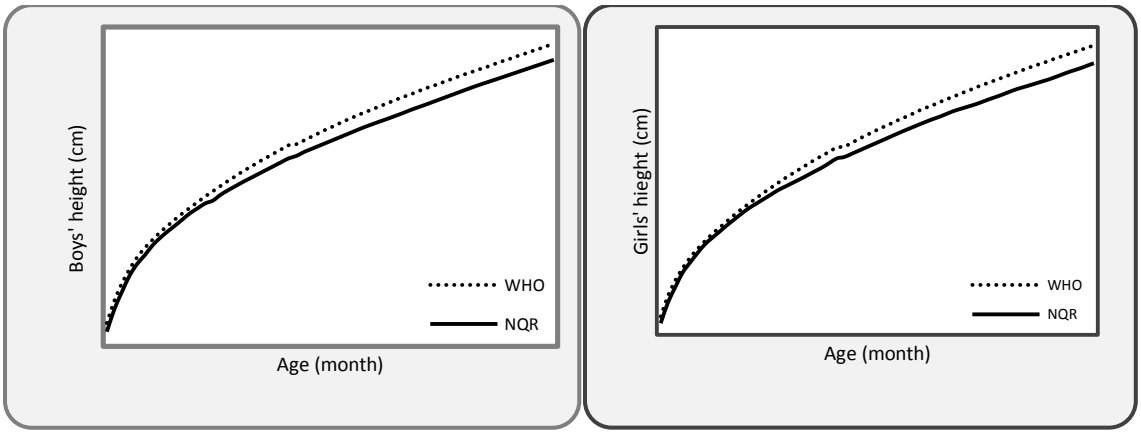


Figure 2: Reference curves in 5th, 50th (median) and 95th percentiles obtained with NQR method using LCKECQ for the northeastern of Iranian girls aged 0-5 years



(a)(b)

Figure 3: Comparison of WHO growth curves and NQR method using LCKECQ growth curves for 50th percentile (median) of northeastern Iranian children from birth up to age 5: (a) for boys; (b) for girls

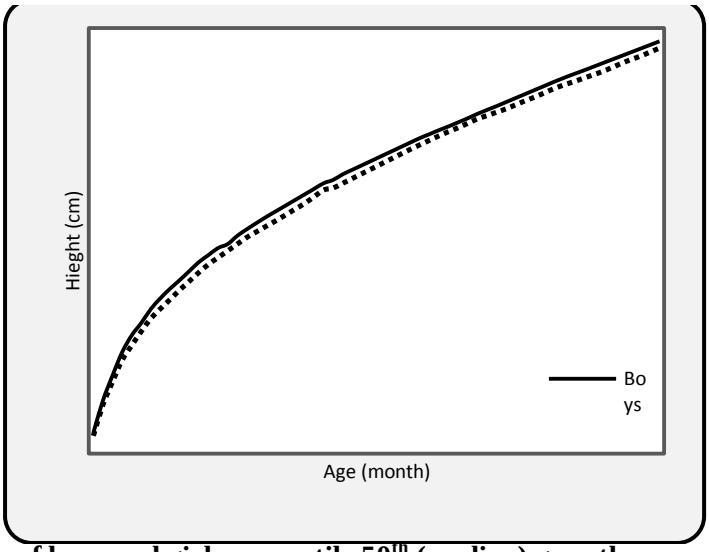


Figure 4: Comparison of boys and girls percentile 50th (median) growth curves of height using NQR method based on LCKECQ of northeastern Iranian children from birth up to age 5

Table1: The 50th percentiles (median) values of height-for-age through both non-parametric quantile regression (NQR) estimation method and WHO standard values for the boys and the girls

	Boys		Girls			Boys		Girls	
Age	Northeast of Iran	WHO	Northeast of Iran	WHO	Age	Northeast of Iran	WHO	Northeast of Iran	WHO
0	48.06	49.9	47.62	49.1	30	89.00	91.9	87.86	90.7
1	52.86	54.7	52.22	53.7	31	89.67	92.7	88.57	91.4
2	56.56	58.4	55.62	57.1	32	90.33	93.4	89.29	92.2
3	60.00	61.4	58.83	59.8	33	91.00	94.1	90.00	92.9
4	62.50	63.9	61.00	62.1	34	91.66	94.8	90.67	93.6
5	64.33	65.9	63.08	64	35	92.25	95.4	91.33	94.4
6	66.40	67.6	65.00	65.7	36	92.85	96.1	92.00	95.1
7	68.00	69.2	66.44	67.3	37	93.40	96.7	92.63	95.7
8	69.40	70.6	67.80	68.7	38	94.00	97.4	93.20	96.4
9	70.67	72	69.21	70.1	39	94.60	98	93.86	97.1
10	72.00	73.3	70.50	71.5	40	95.25	98.6	94.50	97.7
11	73.33	74.5	71.80	72.8	41	95.83	99.2	95.00	98.4
12	74.38	75.7	73.00	74	42	96.40	99.9	95.50	99
13	75.42	76.9	74.00	75.2	43	97.00	100.4	96.00	99.7
14	76.00	78	75.00	76.4	44	97.60	101	96.60	100.3
15	77.23	79.1	76.00	77.5	45	98.20	101.6	97.20	100.9
16	78.20	80.2	77.00	78.6	46	98.80	102.2	97.75	101.5
17	79.11	81.2	77.81	79.7	47	99.40	102.8	98.38	102.1
18	80.00	82.3	78.63	80.7	48	100.00	103.3	99.00	102.7
19	80.83	83.2	79.43	81.7	49	100.57	103.9	99.53	103.3
20	81.67	84.2	80.29	82.7	50	101.11	104.4	100.00	103.9
21	82.50	85.1	81.14	83.7	51	101.64	105	100.50	104.5
22	83.33	86	82.00	84.6	52	102.18	105.6	101.00	105
23	84.17	86.9	83.00	85.5	53	102.73	106.1	101.50	105.6
24	85.00	87.8	84.00	86.4	54	103.27	106.7	102.10	106.2
25	85.50	88	84.30	86.6	55	103.82	107.2	102.71	106.7
26	86.33	88.8	85.00	87.4	56	104.36	107.8	103.29	107.3
27	87.00	89.6	85.71	88.3	57	104.91	108.3	103.80	107.8
28	87.67	90.4	86.43	89.1	58	105.45	108.9	104.40	108.4
29	88.33	91.2	87.14	89.9	59	106.00	109.4	105.00	108.9

Conclusion

We have presented a practical approach to draw height growth charts through utilizing NQR, which can also be applied for other growth charts such as weight and Body Mass Index (BMI). Since the target data used were reference data, the constructed charts could be used as reference growth charts(12).

Our findings showed flexible ability of NQR for handling the growth curve estimation problems. Although NQR with local constant kernel estimation needs extra effort in comparison with parametric and semi-parametric methods, NQR does not require restricted assumptions. Therefore, it is proposed for reference curves and normal values estimation. Another advantage of using NQR for growth curves is the ability to extend the conventional unconditional models depending only on the subjects' age to models that contribute priorities and some other covariates (11).

Some dissimilarities between northeastern of Iranian children growth pattern versus international ones necessitate using local growth curves. World Health Organization norms may lead us to misclassification of abnormality for growth problems in the Iranian children, thus, probably misleading for our healthcare system. To achieve this important goal, the current paper recommends using proposed nonparametric quantile regression with special above mentioned functions and advantages.

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