Longitudinal Standards for Growth Velocity of Infants From Birth to 4 Years Born in West Azerbaijan Province, Northwest Iran

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**Running Title:** Longitudinal Standards for Growth Velocity of Infants.
Abstract:

Objectives: Growth velocity standards are important components to monitor for appropriate child growth. This study aims to present growth velocity of infants for length, weight, and head circumference.

Methods: This study includes 308 neonates (160 boys and 148 girls) born in West Azerbaijan Province, northwest of Iran, and followed from birth for 4 years. Weights and lengths of the subjects were recorded at birth, one, two, four, six, nine months and 1, 1.5, 2, 3 and 4 years of age, while the head circumferences were measured just up to 1.5 years of old. In this study LMS method using LMS chart maker software, was utilized to obtain growth velocity centiles.

Results: Growth velocity charts for weight, length and head circumference (5th, 50th, 95th percentiles) were obtained. The velocity growth charts decreased rapidly from birth to 2 years of old and then remained relatively constant up to 4 years for both sexes. Growth velocities for length and weight of boys in the present sample are slightly but not significantly greater than those in girls through the first months of infancy and no significant difference was seen up to 4 years.

Conclusions: The paper provided the first local growth velocity standards of length, weight and head circumference for infants by analyzing longitudinal measurements produced for West Azerbaijan province which should be updated periodically. It seems that there is significant difference between the growth velocity of infants in northwest of Iran compared with southern within the past few years.

Keywords: Growth, velocity, weight, length, head circumference.
Introduction

Growth is one of the human body’s most complex processes. Each body part or region has its own unique growth patterns [1]. Monitoring health status, identifying deviations from normality, finding out the effectiveness of interventions and health planning of a population can be detected and determined through the babies’ physical growth evaluation [2]. Monitoring of physical growth and development is a important component of primary health care in pediatrics [3].

Anthropometric measurements are important indices of health in children and the most appropriate way to evaluate nutritional and general health status of a community [1, 3]. Weight, height and head circumference are most common parameters of infants physical growth [4].

Among the above mentioned parameters weight is the most widely used measurement since it is the easiest method for an infant's health assessment which is really sensitive to short-term effects [4, 5].

The next most-used measurement in clinical circumstances is that of a regular measurement of head circumference which is especially used by neonatologists and those caring for infants. The two groups of disorders known as a large and small head can be detected through the above mentioned measurement [5, 6]. The third helpful measurement is that of length since stunting originates in the first two years of life, and detecting changes in the velocity of growth during this period may be beneficial in terms of prevention [5].

There are two desirable approaches that detecting the changes in growth of infants, a) comparison of the attained growth at a specific age with a reference chart and, b) growth velocity that measure the growth changes within a time interval [7]. Velocity represents what is happening now, whereas attained growth represents the sum of all that has happened in the past.[4]

Attained growth is the most widely used means of assessing whether a child’s growth pattern deviates from normality. This approach analyzes growth with age in a static way. In contrast, growth velocity measurement is a dynamic process, which takes age into account over a period of time, and is more valuable in the assessment of growth compared with attained size [2, 8, 9].
Further, factors affect growth velocity directly, whereas their impact on attained size becomes evident only after altered rates of growth are sustained for critical periods [5, 10]. In other words, earlier recognition of growth problems would come true by rather than the sheer measurement of attained growth [5].

However, there are far fewer velocity references than for attained growth, due to a scarcity of appropriate longitudinal data sets. The development of a reliable longitudinal growth standard is time consuming because of the requirements of a large patient population, long follow-up times, and careful handling and analysis of data [11].

In Iran, many studies investigated the attained growth standards [6, 12-15], but few surveys have investigated growth velocity standards [4, 16]. To the best of our knowledge, at present time, no study has assessed growth velocity in West Azerbaijan province, northwest Iran. Therefore, this study aims to present growth velocity standards from longitudinally measured boys and girls of 0–4 years of age born in West Azerbaijan, for length, weight, and head circumference. We also compared the growth velocity for weight and length with our previously obtained charts in Shiraz, Fars, southern Iran [16], as well as published values from the U.K.[17].

Materials and Methods:

The current study is longitudinal study and includes measurements of weight, length and head circumference of 308 healthy neonates (160 boys and 148 girls) who were randomly selected in a multistage sampling procedure from the nine counties (Urmia, Miandoab, Takab, Khoy, Mahabad, Bukan, Poldasht, Chaldoran, Salmas) of West Azerbaijan province in 2008 and followed from birth until the age of 4 years at the health centers.

West Azerbaijan province, one of the 31 provinces of Iran, is located in northwest of the Iran which borders with Turkey, and has 27 counties. The province covers an area of 39,487 km², or 43,660 km² including Urmia Lake, with a population 3 million and average annual growth rate of and 1.4. Urmia is the capital and largest city of the province. The climate of the province is largely influenced by rainy winds from the Atlantic Ocean and the Mediterranean. Cold northern winds affect the province during winter and cause heavy snow [18].
A questionnaire on demographic information and health status of the neonates and their parents including gender, child rank, parents’ age, parents’ education and anthropometric measurements was completed. Infants were visited at various target ages (birth, 1, 2, 4, 6, 9, 12, 18, 24, 36 and 48 months) and their weight, length and head circumference were measured by trained health staffs. The weights were measured to the nearest 10 g until the second year of age using a baby scale and onwards to 0.1 kg and the heights or lengths were measured in a supine position until one year of age to the nearest 0.1 cm and then in a standing position, without shoes, in centimeter, using a SECA marked stadiometer and the techniques presented by Cameron, which have been fully described elsewhere [19]. Birth weights of 11 subjects (3.7%) were under 2500 g (range, 1300–2400 g).

Growth velocity was calculated as

\[ V = \frac{M_{n+1} - M_n}{\Delta t} \]

in which \( M_n \) and \( M_{n+1} \) were measurements at adjacent occasions, and \( \Delta t \) was the time interval between them [20]. Because each measurement has its own measurement error, the variance of \( V \) is given by

\[ \text{var}(V) = \sigma^2 + 2\varepsilon^2/\Delta t \]

where \( \varepsilon \) is the measurement error and \( \sigma \) is the population standard deviation of the true measurement velocity. This indicates that the variability of velocity depends on the time interval, \( \Delta t \), between measurements. The velocity standards must be constructed in a particular time interval. For anthropometric measurements during childhood one year is common, which removes any seasonal variation in measurement that is advantage of this interval. For length and weight during infancy a period of a year is too long, and intervals between 2 weeks and 3 months have been proposed and infants are usually measured at irregular time intervals.[20-22]
Then Lambda-Mu-Sigma (LMS) method was applied to calculate growth velocity curves for weight, length and head circumference measures, separately for each gender. The LMS method is a popular method to obtain smoothed centile curves [23].

Each centile curve is summarized by three curves representing the median (M), the coefficient of variation (S) and the skewness of distribution (L) as they change with the independent variable (age), the latter expressed as a Box-Cox power [17]. When the distribution is skewed and kurtotic, z-scores do not have a valid interpretation. Thus we need to transform the distribution to (Gaussian or approximately so) before z-scores can be correctly used. Here in comes the role of LMS method. LMS method is primarily for correcting skewness. Using penalized likelihood the three curves can be fitted as cubic splines by non-linear regression, and the extent of smoothing required can be expressed in term of smoothing parameters or equivalent degree of freedom [1].

The software packages used for construction of growth velocity charts were the LMS Chart Maker (professional), SPSS version 11.5 and Microsoft Excel.

**Results**

The Frequency of subjects and measurements at various target age are summarized in Table 1.

| Table 1 |
| Figures 1, A, B and C show velocity charts obtained for weight, length and head circumference for median and extreme centiles, respectively. |

**Figures 1**

Fig.1, A and B illustrate the weight and length velocity charts of boys and girls. As can be seen, for all centiles, boys' and girls' charts were close to each other, even in some parts the curves overlay each other exactly, except for the younger children (less than 18 months), where the girls' 95th centile falls slightly below the boys'.

Fig.1, C shows the head circumference growth velocity charts by gender. It shows that girls had higher velocity early months after birth. Then, they had a slightly lower velocity and after 12 months, girls had a higher velocity again in 95th centile. For other centiles, boys' and girls' charts were close to each other, again the curves overlaying each other exactly in some parts.
In addition, Figures 2 and 3 compared velocity charts of weight and length in the present study with the shiraz study charts that carried out in 2005 [16]. Figure 2, show that Growth velocity charts for weight in south of Iran lie below those of northwest of Iran standards in both sexes.

Discussion

Growth velocity standards are efficient components as screening tools to assess short-term changes in growth rate of children so considered for primary health care in pediatrics. The present study used longitudinal data to estimate growth velocities from birth until the age of 4 years on a fairly large number of individuals.

Growth velocity measures obtained during the last measured interval (1 month for the first 2 months of the infant’s life, bimonthly in the next 4 months, 3 months for the second 6 months, 6 months for the second year and 12 months for the third and fourth years). Whereas Shiraz data were available at different intervals [16].

Growth velocities for length and weight of boys in the present sample are slightly but not significantly greater than those in girls through the first months of infancy, as can be seen in Figures 1, A and B. Figures 2-3 compare weight and length velocity charts with the data from Shiraz for both sexes, respectively.

Weight velocity standards in the infants of this study were significantly higher than Shiraz but similar to U.K. counterparty and more pronounced in the first year of life [17]. Table 2 compares the median of length and weight velocities of West Azerbaijan, Shiraz and U.K. infants by sex and age. These studies reported pronounced sex differences in the velocity measurements.

Our subjects were healthy infants without evidence of malnutrition who were monitored during the course of the study. The existing differences between the studied populations lead us to propose local growth velocity standards for south and northwest of Iran separately.
The structural representativeness of our sample to that of principal provinces of northwest of Iran in terms of socioeconomic, demographic, and environmental factors suggest that our growth velocity standards are appropriate for northwest of Iran. Therefore it may not be representative of the entire population of Iran.

Growth of children in an urban region may differ from the growth of children who live in rural areas. Socio-environmental conditions as well as nutritional status may be different between children living in urban and rural areas [24, 25]. Advantage of this study lies in providing a representative sample which comprises major of regions (rural and urban) in a well designed longitudinal study, while the earlier surveys were based on infants attending urban regions, who were unlikely to form a representative population sample. However, we suggest that due to changing characteristics over time, data should be used from different parts of the country. This way the local charts can be updated and even more representative.

Based on our findings, generally the growth velocities for the present sample are significantly greater than those in southern parts of Iran in almost all sex groups; this might be due to changes in lifestyle such as socioeconomic status, nutritional factors, living conditions, health and cultural developments due to modernization process and rapid urbanization which occurred in Iran in recent years. In addition, changing dietary habits, physical attributes, access to health care and education can influence this secular trend in growth velocity standard as a reliable measure for monitoring child growth [26, 27]. Finally, this could be attributed to genetic, environmental and infants’ feeding pattern. Therefore, our data supports the fact that updated local standard growth velocity should be used.

A major difference between the present study and previous ones is the statistical method that was applied for constructing growth velocity curves. In the present study parametric LMS method was used, many studies used this model to make growth velocity [7, 28]. As Patel et al. implied, LMS model provided an accurate estimate of growth velocity [28]. In the study of Ayatollahi et al. in 2013, the parametric LMS method was used to construct reference centiles curves for different measurements [29].

This method has the advantage that after a suitable power transformation the data are normally distributed and as a result it provides more smooth centiles. Another advantage of the LMS method is that the three curves, L, M and S, completely summarize the measurement’s
distribution over the range of covariates, and in addition they may be interest in their own right. A key assumption of the LMS method is that after a suitable power transformation the data are normally distributed. Anthropometric measurements, particularly weight and height, tend to follow this pattern [30]. In the previous [16] study nonparametric Healy-Rasbash-Yang (HRY) method was applied. Before applying this method on anthropometric measurements, some transformation such as log transformation should be applied for normalizing the variables.

Although this study has major strengths with respect to collection of data in a relatively large cohort of neonates from 0-4 ages, it also shows the inevitable difficulties and some limitations of such a long-term study. One limitation of our study is that, Nine counties are restrict regions of West Azerbaijan, therefore it may not be representative of the entire population of West Azerbaijan province children. Another limitation is that, We did not account the effect of important confounding factors such as body weight and body mass index; hence we recommended using more reliable and accurate methods than just considering the age of children in future studies.

**Conclusion**

In conclusion, the paper provided the first local growth velocity standards of length, weight and head circumference for infants by analyzing longitudinal measurements produced for West Azerbaijan province (northwest Iran) which should be updated periodically. It seems that there is significant difference between the growth velocity of infants in northwest of Iran compared with southern within the past few years. However, further research is needed on Iranian children in different provinces to determine the most reliable and valid index representing accurate assessment of growth velocity.

**Acknowledgments**

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**Conflict of Interests**

None

**References**


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![Graph A](image1.png)  
![Graph B](image2.png)  
![Graph C](image3.png)
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