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Determining the Z Scores of Children Covered by Mashhad University of Medical Sciences and Comparing it with the WHO and CDC Standards

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ABSTRACT

Background: The World Health Organization has introduced two sets of child growth standards for growth assessment. These reference values may not be suitable for use in other populations. Therefore, this study aimed to determine specific Z scores in the population covered by Mashhad University of Medical Sciences in Iran.

Methods: This cross-sectional study was conducted on data obtained from the evaluation of height, weight, and head circumference of children aged from 0 to 18 months visiting the healthcare centers of Mashhad University of Medical Sciences from March 2018 to March 2021. A total data of 128,472 children were extracted from the Electronic Health Records (SinaEHR®) and included in the study. Finally, the collected data were analyzed using Minitab and SPSS software (version 16).

Results: The L, M, and S parameters were used to calculate Z scores for weight, height, and head circumference. These Z scores were then compared to standard deviation values for each age from our study and international standards to determine any differences. Our study found that mean weight scores were 0.16 kg higher than the CDC standard and 0.34 kg higher than the WHO growth standard.

Conclusion: The provision of this exclusive reference to children's growth indicators not only allows for a more accurate evaluation but also provides the possibility of comparison with other populations using their specific growth charts. It seems that one of the best plans is to compare growth charts with international populations and national growth charts, which due to the electronization of the entire processes of the health system, is more possible than ever.

Keywords: Growth chart, Head circumference, Height, LMS method, Reference values, Weight

Introduction

A child's normal growth is defined as changes in height, weight, and head circumference consistent with established standards for the given population. Normal growth reflects the overall health and nutritional status of the child and should be interpreted in the context of the child's genetic potential. Understanding the normal patterns of growth enables early diagnosis of pathological deviations (e.g., poor weight gain due to metabolic disorder, and non-constitutional short stature) and may prevent unnecessary evaluation of children with acceptable normal growth variations.

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Physical growth and biological maturation are influenced by multiple factors acting independently but in concordance with one another to modify a child's genetic developmental potential. The primary influence on growth parameters at birth and during the first month of life is caused by maternal nutrition and intrauterine environment, while genetic factors play a role later in a child's life (1).

The correlation coefficient between weight and height at birth is only 0.25; however, it increases to 0.8 at two years of age, which is mainly reflected in growth parameters at birth (2, 3). The long-term effects of the mother's nutrition and intrauterine environment are revealed later in life and during the puberty period (4, 5).

Most healthy infants and children grow in a predictable manner, following a typical pattern of weight, height, and head circumference development. Normal human growth has a pulsatile manner with periods of rapid growth ("growth spurts"), followed by periods of no measurable growth (6-8).

One of the main functions of any healthcare system is to monitor children's growth, and various tools are needed to carry out this obligation, at the top of which lie growth charts, and most health systems use standardized tools called standard or reference charts.

Growth charts were first designed by the United States National Center for Health Statistics (NCHS) and approved by the World Health Organization (WHO), and have been used internationally since 1978 under the title of NCHS/WHO growth charts (9). Weight and height growth in well-nourished children under 5 years of age from different races, ethnicities, and countries are usually similar; therefore, the use of international growth standards is widely accepted (9).

The current internationally used growth reference emerged from two data sources consisting of data from a longitudinal study from 1929 to 1975 by Fels Research Institute, which calculated the specific height-for-age, weight-for-age, and weight-for-height Z scores of children under 36 months, and three national studies which assessed growth indexes of 2-18-month children (10).

Due to the increased awareness of the shortcomings of the then-available charts, the United States Center for Disease Control and Prevention (CDC) revised the NCHS charts and republished them in 2000 (11). Later, the WHO also published new sets of growth charts in 2006 based on an international sample of breastfed children which serve as a standard for how children grow (12).

The design of these new charts was based on a multicenter study involving 6 countries of America, Brazil, Norway, Ghana, Oman, and India. Despite the universal use of these charts, different countries have also designed their own standards over time.

Standard curves are actually a practical and simple form of normal values expressed as a mean and two standard deviations. The 50th percentile or the median of the curves is actually the normal average of height, weight, or head circumference of children at that age. The minimum acceptable or minus two standard deviations is equivalent to the 3rd percentile, and the maximum acceptable or plus two standard deviations is equivalent to the 97th percentile. Values below the 3rd percentile and above the 97th percentile are usually considered abnormal. The mean and two standard deviations usually include 95% of the cases; accordingly, in some graphs, the 5th and 95th percentiles are used instead of the 3rd and 97th ones (13).

In recent decades, despite the existence of standard growth charts by authoritative sources, such as WHO-2006, CDC-2000, and NCHS-1997, various countries have tried to take cultural, genetic, and climatic differences into account and have therefore conducted their own native studies to estimate their own Z scores to show the effectiveness of having a national growth standard, compared to using the international references (14-19)

Some studies conducted inside Iran have also demonstrated some differences between the international growth standards and the native ones (20). A recent meta-analysis study has also noticed the global variability of human growth, which indicates the insufficiency of using a single growth chart for all countries (21).

Due to the importance of assessing the appropriateness of using international standards at a national level and in specific regional populations, this study aimed to determine the specific Z scores of weight, height, and head circumference of Iranian children under the age of 18 months covered by Mashhad University of Medical Sciences and compare them with WHO and CDC-2000 standards.

Methods

Children aged 0 to 18 months have a total of 11 standard growth evaluations measuring height, weight, and head circumference, which include 3 visits in infancy, 5 visits from 1 month to the end of infancy (at 2, 4, 6, 7, and 9 months), and 3 visits at 12, 15, and 18 months.

In the implementation of this cross-sectional study, children from non-multiple pregnancies with no history of maternal or genetic diseases who completed all 11 visits in comprehensive urban and rural health service centers under the coverage of Mashhad University of Medical Sciences and had their data successfully registered in their electronic profile between March 2018 and March 2021, were eligible to be included in the study. Reviewing the data in the SINA Electronic Health Records indicated that a total of 128,472 children met the inclusion criteria, and therefore, they entered the study based on the census procedure.

Standard Z scores of weight-for-age (WAZ), height-for-age (LAZ), and weight-for-height (WLZ) were calculated based on WHO and CDC-2000 standards, and then, the LMS method was used to estimate the specific Z scores for the Iranian children covered by Mashhad University of Medical Sciences. The parameters of this method are composed of the median (M), normalized coefficient variation (S), and normalization ability (L), which show central tendency, dispersion, and skewness, respectively (12).

To smooth the data, we utilized LMS Chart Maker 2.1 software. In this approach, LMS values were transformed into a normal distribution using the Box-Cox method. Similarly to Cole et al.'s method, any outliers were excluded from the final analysis. For height, weight, and head circumference variables, scores ranging from -3 to 3 were computed. The standard deviation score was employed to compare the statistical differences between the values obtained in this study and other established standards.

This study was conducted on the previously registered data without any interventions and on this basis, the necessary ethical considerations were taken into account. The data for the study were collected anonymously and using codes; therefore, the personal details of participants remained confidential.

Ethical approval

The proposal for this research was presented to the Organizational Ethics Committee of Mashhad University of Medical Sciences on July 30, 2019, with the reference number 980289, and was approved with the code of IR.MUMS. MEDICAL.REC.1398.442.

Results

In total, 51.5% of the children were boys and the rest were girls. The mean and standard deviation of weight, height, and head circumference for the age were analyzed from birth to 18 months. In comparison, the growth in boys was slightly higher than that of girls of the same age.

As already stated, height, weight, and head circumferences of the participating children were measured 11 times, which include 3 visits in infancy, 5 visits from 1 month to the end of infancy (at 2, 4, 6, 7, and 9 months), and 3 visits at 12, 15, and 18 months. The means of these evaluations are displayed in diagrams 1 to 3.

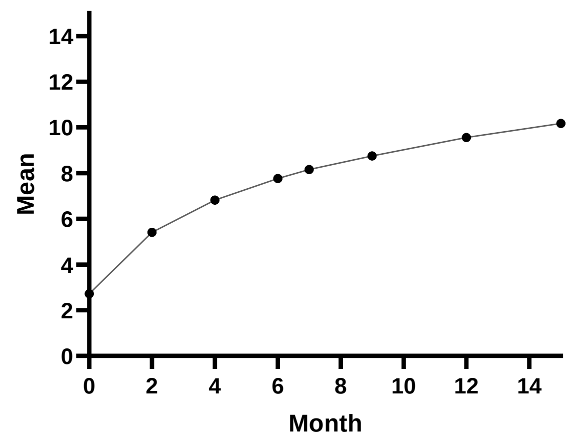

Figure 1. The mean weight based on age (month)

Weight and height for age Z scores calculated for children from birth to 18 months are demonstrated in Tables 1 and 2. Tables 3 and 4 display the comparison of weight and height Z scores for the participating Iranian children with the CDC and WHO standards.

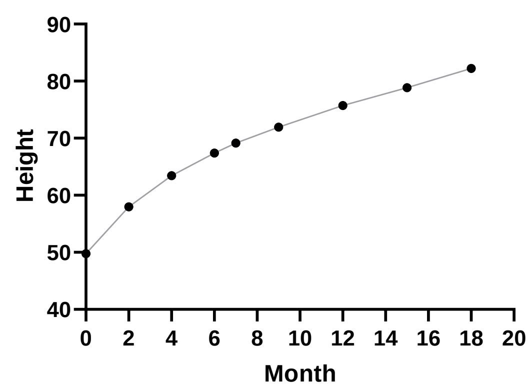

Figure 2. The mean height based on age (month)

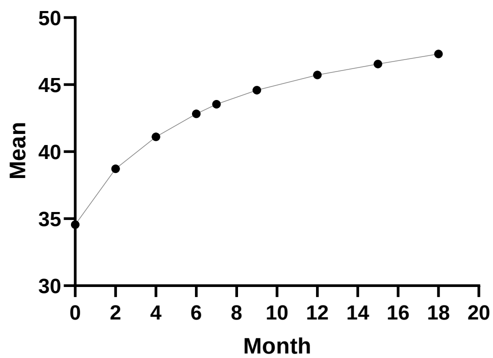

Figure 3. The mean head circumference based on age (month)

Table 1. Weight for age Z scores calculated for children from birth to 18 months

Age	Power [L]	Median [M]	Variation [S]	SD	-3	-2	-1	0	+1	+2	+3
0	0.98	2.70	0.05	0.14	2.29	2.43	2.56	2.7	2.83	2.97	3.10
2 mos	0.53	5.40	0.13	0.74	3.48	4.08	4.71	5.4	6.12	6.88	7.69
4 mos	0.81	6.80	0.12	0.8	4.44	5.20	8.99	6.8	7.62	8.46	9.32
6 mos	-1.22	7.70	0.12	0.97	5.71	6.23	6.88	7.7	8.76	10.22	12.37
7 mos	-0.17	8.16	0.12	1	5.72	6.42	7.23	8.1	9.23	10.46	11.90
9 mos	0.21	8.7	0.12	1.06	5.96	6.78	7.69	8.7	9.80	11.01	12.34
12 mos	-0.78	9.5	0.12	1.17	6.88	7.59	8.45	9.5	10.79	11.45	14.61
15 mos	-1.03	10	0.11	1.19	7.41	8.10	8.95	10	11.32	13.07	15.45
18 mos	-0.83	10.8	0.12	1.34	7.82	8.63	9.60	10.8	12.29	14.22	16.77

Table 2. Height for age Z scores calculated for children from birth to 18 months

Age	Power [L]	Median [M]	Variation [S]	SD	-3	-2	-1	0	+1	+2	+3
0	1.34	49.7	0.04	2.14	43.6	45.66	47.69	49.	51.67	53.62	55.54
2 mos	-0.53	57.9	0.04	2.73	51.54	53.53	55.65	57.9	60.28	62.83	65.54
4 mos	1.81	64	0.04	2.73	55.90	58.70	61.39	64	66.51	68.96	71.34
6 mos	-1.12	67	0.03	2.70	60.02	62.17	64.49	67	69.72	72.69	75.95
7 mos	3.65	68.9	0.039	2.74	59.14	62.85	66.06	68.09	71.45	73.79	75.95
9 mos	4.14	72	0.03	2.87	61.35	65.52	69	72	74.65	77.03	79.2
12 mos	1.35	75.7	0.03	2.95	67.12	70.02	72.88	75.7	78.48	81.23	83.94
15 mos	-0.16	79	0.03	2.99	70.02	73.29	76.13	79	81.48	85.10	88.36
18 mos	4.01	83	0.03	3.18	71.27	75.80	79.64	83	85.98	88.69	91.16

Table 3. Comparison of weight Z scores estimated for the Iranian children with CDC and WHO standards*

Age	-3		-2		-1		0		+1		+2		+3	
	Difference with		Difference with		Difference with		Difference with		Difference with		Difference with		Difference with	
	CDC	WHO	CDC	WHO	CDC	WHO	CDC	WHO	CDC	WHO	CDC	WHO	CDC	WHO
0	-0.1	0.2	-0.2	0	-0.3	-0.3	-0.6	-0.5	-1	-0.9	-1.1	-1.3	-1.2	-1.7
2 mos	-0.2	0	0.1	0.1	0.5	0.2	0.6	0.3	0.6	0.3	1	0.2	1.5	0.1
4 mos	-0.3	0	0.2	0.2	0.5	0.2	0.7	0.4	0.7	0.3	1.1	0.2	1.6	0
6 mos	0.1	0.6	0.2	0.5	0.4	0.3	0.5	0.4	0.7	0.5	1.7	0.9	3.3	1.7
7 mos	-0.3	0.4	0	0.4	0.4	0.4	0.5	0.5	0.7	0.6	1.4	0.6	2.4	0.8
9 mos	-0.8	0.1	-0.4	0.2	0	0.3	0.2	0.5	0.4	0.5	1.1	0.6	1.8	0.3
12 mos	-0.9	0.5	-0.6	0.5	-0.1	0.5	0	0.6	0.1	0.6	0.3	-0.1	2.8	1.5
15 mos	-1	0.7	-0.7	0.5	-0.4	0.4	-0.3	0.4	-0.1	0.4	0.9	0.6	2.6	1.3
18 mos	-1.1	0.6	-0.8	0.5	-0.3	0.5	-0.1	0.6	-1.4	-0.8	1.3	1	3	1.6

* To estimate the difference, the values calculated for this study were subtracted from CDC and WHO values.

Table 4. Comparison of height percentiles estimated for the Iranian children with CDC and WHO standards*

Age	-3		-2		-1		0		+1		+2		+3	
	Difference with		Difference with		Difference with		Difference with		Difference with		Difference with		Difference with	
	CDC	WHO	CDC	WHO	CDC	WHO	CDC	WHO	CDC	WHO	CDC	WHO	CDC	WHO
0	-0.9	-0.6	-0.24	-0.44	0.39	-0.31	-0.2	-0.2	-0.93	-0.13	-0.28	-0.08	0.34	-0.06
2 mos	-1.86	-0.86	-0.97	-0.87	-0.5	-0.75	-0.2	-0.5	-0.42	0.12	0.83	0.43	2.04	1.14
4 mos	-2.6	-1.7	-0.9	-1	0.69	-0.41	0.9	0.1	0.71	0.51	1.76	0.96	2.64	1.24
6 mos	-2.18	-1.18	-1.13	-1.13	-0.01	-1.01	0.1	-0.6	0.02	-0.08	1.49	0.79	3.25	1.95
7 mos	-4.56	-3.56	-2.05	-1.95	-0.04	-0.94	0.3	-0.3	0.05	0.15	0.89	0.29	1.45	0.25
9 mos	-5.15	-3.85	-2.18	-1.98	0.1	-0.7	0.4	0	0.15	0.45	1.03	0.53	1.6	0.5
12 mos	-2.88	-1.448	-1.28	-0.98	0.18	-0.52	0.2	0	-0.02	0.38	1.13	0.73	2.14	1.04
15 mos	-2.24	-0.84	-1.01	-0.71	0.23	-0.47	0.2	-0.1	-0.52	-0.22	1.4	0.9	3.06	3.66
18 mos	-4.33	-2.93	-1.4	-1.1	0.94	0.04	1.1	0.7	0.78	0.98	1.79	0.99	2.56	0.76

* To estimate the difference, the values calculated for this study were subtracted from CDC and WHO values.

Discussion

The standard Z score has been introduced as the best system for displaying and analyzing anthropometric data both at the individual level and at the cumulative level (22).

LMS parameters and the Z score of growth reference are considered important tools both for research and healthcare evaluations. Regular assessment of children's growth and nutritional status is mandatory, especially for those affected by chronic medical conditions influencing their growth and nutrition, such as inflammatory bowel disease. In addition, the availability of LMS parameters of standard Z scores allows the integration of growth charts in electronic health records along with international growth charts.

Although in some Iranian studies, L, M, and S, as well as the Z scores for children's growth, have been estimated, due to insufficiency of sample size and low generalizability, none of these estimations can reflect a large-scale image of the national indexes. However, this study is considered one of the largest studies carried out in Iran. The provision of this exclusive reference to children's growth indicators not only allows for a more accurate evaluation but also provides the possibility of comparison with other populations using their specific growth charts.

In examining the difference between weight Z scores calculated for the population covered by Mashhad University of Medical Sciences, as well as CDC and WHO standards, it was revealed that the mean weight scores are 0.16 kg higher than that of the CDC standard (range of variation: -0.6_0.7) and 0.34 kg higher than the WHO growth standard (range of variation: -0.5_0.6). In addition, Z scores calculated for children at birth are below international standards almost in all standard deviations; however, for other ages, the values calculated for this study are below CDC standard values and above WHO standards.

The weight difference with the CDC and WHO standards in -3 standard deviation, which is the cut-off point for extremely underweight, is on average -0.51 kg and 0.32 kg, respectively, and in -2 standard deviation, which is the cut-off point for being underweight, the difference is -0.3 and 0.36 kg, respectively (Table 3).

The median height-for-age value in this study is on average 0.31 cm higher than the CDC standard and 0.1 cm lower than the WHO standard. Moreover, the height percentile difference values are lower than the CDC and WHO growth standards in all standard deviations for short stature. However, for +1 to +3 standard deviations (tall stature spectrum), values calculated for this study are generally higher than the CDC and WHO standards, except for values right after birth.

The findings of this study are in line with the results of other studies in other countries, such as Asif in Pakistan, Bong in Malaysia, Reddy in India, Ouyang in China, Del Pino in Argentina, and Brown in Rwanda (18-22) in showing differences in the native growth standards with international standards.

In a study by Del Pino et al. to obtain a native model of growth indices including height, weight, and head circumference in Argentinian children with achondroplasia on 228 children (114 boys and 114 girls) aged 0 to 18 months, a reliable native model in the target population was achieved (14).

Brown et al. evaluated and compared the information collected manually and electronically by 24 healthcare workers in both urban and rural populations. The data analysis revealed the information obtained electronically to be more accurate and more efficient than the standard growth curve of the WHO (15).

In a study in Pakistan on 10,668 healthy Pakistani children, it was concluded that the WHO 2007 standard growth chart is not suitable for Pakistani children (18). A similar study in Malaysia concluded the same results (19). Issues including inappropriate sample size, heterogeneous distribution, and focusing on populations with specific diseases may be the reasons for such differences with international standards.

The limitations of the study include the loss of data. Incomplete registration of information in the SINA Electronic Health Registration System plays a big role in data loss. This weakness can be solved to a great extent by better training healthcare providers who work with the SINA system.

Conclusion

The results of this study can be submitted to the Office of Health and Nutrition Management of the Ministry of Health, and after approval, the results may be used for national comparisons.

It is suggested that in the future, the electronic health system be set up and available in the private sector and other parts of the health system so that more accurate information can be extracted.

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Conflicts of interest

The authors declare that there is no conflict of interest.

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