Growth charts for Saudi children and adolescents

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ABSTRACT

Objectives: To establish reference growth charts for Saudi children and adolescents.

Methods: Multi-stage probability sampling of a cross-section of Saudi children and adolescents residing in all 13 regions of the Kingdom. Family interviews, and physical examinations of children and adolescents from birth to 19 years of age were conducted over a 2-year period (2004-2005). Only healthy children and adolescents were included for the measurement of length/stature, weight, and head circumference. All measurements were performed by trained physicians and nurses according to World Health Organization guidelines. Percentile construction and smoothing were performed using the LMS (lambda, mu, sigma) methodology.

Results: Determination of the standard measures for normal physical growth in a sample representing healthy Saudi children and adolescents from birth to 19 years of age.

Conclusion: The results of this study present the most comprehensive and up-to-date reference growth charts for Saudi children and adolescents. Therefore, the authors recommend the use of these charts to replace older charts or those belonging to other countries.

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Provision of high quality health care requires knowledge of normality that helps distinguish health from disease. Many countries have established their own comprehensive growth charts for their children and adolescents.[1,2] However, in the Kingdom of Saudi Arabia (KSA), attempts have been made to assess the growth of children and results were published. In Riyadh City, a previous study on the growth of 6,400 infants and preschool children concluded that Saudi children in Riyadh were slightly shorter and thinner if compared with their American counterparts, using the standards of National Center for Health Statistics (NCHS).[3] Another national study involving 48,000 school children, at the age of 6-18 years, selected by a multistage stratified cluster sampling technique, concluded that the growth pattern of Saudi children was retarded by less than one standard deviation when compared with NCHS standards.[4] Another national study conducted in the school boys from 1994 to 1995 reported a high prevalence of obesity.[5] Other studies, performed independently in different cities and regions, found that the growth pattern of Saudi children was different from their American and European counterparts. These included school children (6-16 years old) from the Eastern Province,[6] and children and adolescents residing in Asir region (4000 boys and 3660 girls, birth to 19 years old, mostly military dependents).[7] The latest report was the result of a national study restricted to children under 5 years of age, and revealed their differences from NCHS growth charts for certain age groups.[8] It is evident that these studies were not designed, and therefore may not be used to develop such growth charts that could be applied nationwide for all Saudi children and adolescents. This is reflected by the continued use of Western growth charts in many hospitals and clinics throughout the country. Finally, in a review article, one of the most prominent Saudi physicians stated that the time is now ripe to create Saudi Standards for health and nutrition to be used as a yardstick for future planning and evaluation of health and nutritional programs.[9] This study was designed as a response to fill this gap by establishing a reference scale for the physical growth of Saudi children and adolescents upon a sample representing the population of all 13 regions of the Kingdom.

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Methods. Guidelines and criteria established by experts in such studies were followed for determination of sample size.[10] It has been already defined that standard body measurements should be obtained from a well-nourished population, the sample should be cross-sectional and include at least 200 individuals in each age and gender group. Moreover, the sampling procedure must be valid, reproducible, and precisely defined; measurements should be carefully made and recorded by observers trained for anthropometric techniques. The latter should use well-tested design and calibrated equipment at frequent intervals. The study sample was determined based on the population census for the KSA, which was available at the time of the study design. It was the census performed in 1992 and updated in the year 2000-2001.[11] A sample size of 42,000 children and adolescents from birth to the age of 19 years was calculated to produce valid results of growth variables that possess the ability of being generalized with standard error not exceeding 5%. Previous studies have showed that the average number of children and adolescents (under 19 years of age) in Saudi households is approximately 3 to 5. A conservative estimation of 3 children and adolescents for each family implies that total of (42,000/3) 14,000 households would be included in this study. These households were randomly selected by a multistage probability sampling procedure from a stratified listing based on the updated 2000-2001 census. This process was completely computerized. It was performed with the assistance of the General Directorate of Statistics, Ministry of Planning that provided all details of the selected households in cities and villages including road and street maps. A pilot study was designed to test all components of the project before data collection. Buraidah city in the region of Qassim was selected for this purpose, and all the investigators participated in one full-day workshop training. Attendance included the regional health supervisor, field team supervisors, doctors, and nurses enrolled in the field teams. The program included oral presentations, small group training in the procedure of locating the selected households, explanation of the questionnaire, family interviews, and clinical examination of children as well as taking body measures, and recording the data in the questionnaire. This also included field visits to demonstrate ways of locating the households in the study sample. Subsequently, 70 households were surveyed and data were collected and sent to the Study Center in the College of Medicine, King Saud University, Riyadh for analysis.The result of the pilot study identified the need to refine certain aspects of methodology, which were accomplished before the actual start of the main study. Workshop training of the field teams was conducted in each of the 13 regions of the Kingdom. The organization was similar to that used for the pilot study. Certain large regions like Riyadh and Makkah required several training sessions. Oral presentations on how to locate the study sample, fill out the questionnaire, hands-on training on the methods of measurement, and finally a field visit to demonstrate the ways of finding the households in the sample. Data collection was performed over a period of 2 years (2004-2005) by house-to-house visits in most cases, however in a few instances, where this was not practical for the families, clinical examination and filling the questionnaire were performed in health centers by the same field teams. The survey questionnaire was designed to provide needed basic information to achieve the objectives of the study. The exact birth date was considered to be particularly important and acceptable only when it was completely recorded (day/month/year) from an official document (mostly birth certificate or family card). The exact date of body measurements was also noted. Both dates, essential for the determination of the exact age at the time of measurement, were recorded in Hegira calendar and subsequently converted to Gregorian dates before calculation of the age at the time of measurements. Information on other factors that are known to affect growth such as perinatal history, nutrition, childhood illnesses, and socio economic status of the family were also recorded. The questionnaire was tested in a pilot study and finalized before the actual data collection. Interviewers (doctors and nurses) were recruited and trained to administer the questionnaire under the supervision of the researchers. The clinical examination of the children and adolescents was performed by physicians, enrolled in the field teams to determine the eligibility for measurements. Only healthy children and adolescents as determined by interview and clinical examination were eligible for body measurements. The methods of anthropometric measurements were adopted according to standard recommendations. Specific guidelines written in Arabic and English languages were distributed to all members of the field teams. For every child at the age of 2 years or less, ***the recumbent length*** was measured while the child was lying on the back over a flat surface, by a measuring rod (Seca, Germany) with a fixed head end, and a sliding feet end perpendicular to this surface. An observer holds the head in contact with the head end board, and another straightens the legs and turns the feet upward to be at right angle with the

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legs and bring the sliding feet end board in contact with the heel of the child. After double-checking to make sure the child is still in the position described above, the measurement is then taken and recorded in Arabic numbers to the last completed 0.1 cm.[12]

Measurement of stature was performed for all children above 2 years of age. The child was standing with bared feet while his/her heels and back were kept in contact with an upright stadiometer board (Seca, Germany). The head is held so that the subject looks straight forward, with the lower border of the eye socket in the same horizontal plane as the external auditory meati. Head covers, and hair clips were removed. A right angle board, perpendicular to the backboard, was slid down until its lower surface touched the head. The subjects were asked to stretch their neck to be as tall as possible. After double-checking of the right position, the height is recorded to the last completed 0.1 cm.[13,14]

Measurement of the weight. The subjects were weighed with minimal clothes. An estimation of 0.1 kg is subtracted to account for these clothes. Children younger than 2 years were weighed lying down on a beam scale, whereas older children were weighed standing. The weight is recorded to the last completed 0.1 kg.

Measurements of the head circumference. The maximum head (skull) circumference was measured using a non-stretchable tape measure. The tape measure was passed around the forehead, fixed above the eyebrows and moved up and down around the occiput to obtain the maximum circumference.

Precautions were taken to insure reliability and accuracy of measurements. These included the use of equipment known for high accuracy (Seca, Germany), frequent calibration at the beginning of each session, and double-checking the weight scales with known weights. In addition, intra- and inter-observer reliability were tested once in each enumeration area.The data were entered into a computer as they became available. A software program published by the Center for Disease Control (CDC) was used.[15] This program was adapted to the needs of this study and used to obtain and collect all data from each subject. An identification number (family ID number) was assigned to each family (questionnaire), and every family member was identified by a subject line number and finally marked by a number (record number). For example, the father is assigned subject line number one, the mother subject line number two and the youngest child was assigned subject line number 3 and so forth. Only data relevant to each subject were entered in his/her record. After arrival in the Riyadh center, the questionnaires were reviewed for completeness by the investigators. Any missing, unclear or incomplete data were checked with the regional and field supervisor and dealt with accordingly. Trained personnel entered data into the above-mentioned program. Data "cleaning" is essential before the actual analysis. Multiple frequency analyses were used to detect any missing data, inconsistencies, and other types of errors. These were repeated until all errors were corrected. Furthermore, the data were evaluated for accuracy by the Anthro program and digit distribution analysis of all measurements, so all questionable data were double-checked. This procedure was very useful in detecting "hidden errors" in records with incomplete data or errors in the methodology, which were either corrected whenever possible or excluded from analysis. The decimal age for children and adolescents at the time of measurements was calculated based on the dates of birth and measurement. Although these were recorded in Hejra calender, conversion to Gregorian dates was necessary for purposes of comparison with other studies. These conversions and calculation of decimal age were performed by computer using published software.[16] Simple descriptive statistics in the form of frequency tables were used in this research to describe the factors that are known to affect growth and development of children including the education, housing, and occupation of the parents and the patterns of feeding and nutrition of the children. Statistical analysis of growth data was performed using the LMS (lambda, mu, sigma) methodology. This method was first proposed by Cole and Green,[17] and is widely regarded as an effective means for estimation of population percentiles. The LMS method assumes that, for an independent positive measurement y(i) at the age t(i), there is an age-specific Box-Cox transformation that can be applied to make y(i) normally distributed. The parameters of this transformation are lambda (controlling skewness), mu (the mean) and sigma (the standard deviation) and, for each set of data, graphical estimates of the values of these 3 parameters as a function of age are given. The strategy was first to optimize the effective degree of freedom (edf) for mu, followed by that of sigma and finally lambda. At each step the edf was changed by one until the change in the log-likelihood fell below 2.0, indicating a nonsignificant difference. The best-fitted model to the data was obtained in some instances by using a 2-stage process based on a monotonic transformation of the age scale.[18] Also, an extension of the LMS methodology by including a fourth Box-Cox parameter for kurtosis (flatness) was used in some instances.[19]

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Results. All randomly selected 14,000 households were covered whether on the top of high mountains in the South (Faifa, Gizan), or in the middle of the desert of the Riyadh Region (Mashthobah). However, only 11,874/14,000 (84.8%) were eligible. The remaining 2,126 households were either vacant, replaced by non-Saudi families, had no eligible children available, or declined participation in the study. There were 8,689/11,874 (73%) of the households in urban and 27% in rural settlements. Data on the type of housing was available for 10,676 families, of which, 4,129 (38.7%) lived in villas, 3,268 (30.6%) in apartments, 2,807 (26.3%) in traditional houses, and 472 (4.4%) in other types of housing. Most families 7,276/10,523 (69%) live in their own houses, 2,626 (25%) in rented, and 621 (6%) live in special arrangements such as free housing in compounds for company employees and military personnel. Data on educational level of the head of households was available in 8,340 households. The highest completed levels of education were university or higher in 1,361/8,340(16.3%), secondary/intermediate school in 34.6%, elementary in 26.1%, illiteracy 19.7%, and others in 3.3%. The jobs of households heads were available for 8,358 households, as followings: 30% were administrative employees, 21.7% military, 19% in private business, 13.5% other occupations, 11.6% retired, and 3.2% unemployed. The gestational age of the children was estimated by history taken from mothers. Every child with a gestational age of less than 8 months (0.9%) or low birth weight of less than 2.5 kg at birth (3.2%) was excluded from the study. Data on feeding and nutrition were collected only for children less than 3 years of age. Out of a total of 5,339 children, 4,889 (91.6%) had a history of breastfeeding, and 480 (8.4%) never breastfed. The most common age at introduction of bottle-feeding was between 1-2 months in 2,116/4,057 (52%) and whole milk feedings were most commonly started around 12 months of age. Solid foods were introduced between 4-6 months of age in 81.9% of the infants. The number of eligible children and adolescents from each region is shown in **Table 1**, indicating balanced distribution of sample proportional to the population size of each region, to ensure adequate representation. **Tables 2 and 3** depict the grouping of children and adolescents. The format used in NCHS and CDC growth charts was adopted for the results of our study because of its simplicity and familiarity to many practitioners in the Kingdom and abroad. There are 2 groups of charts, one for the age group from birth to 36 months and another for the age group from 2 to 19 years, each group of charts consists of 8 figures, (including 4 charts for each

Table 1 - Distribution of the study sample per region.

Region	Eligible children	
	n	(%)
Makkah Al Mokarramah	6430	(18.1)
Riyadh	6395	(18.0)
Eastern province	3810	(11.1)
Aseer	3459	(9.9)
Al Jouf	2347	(6.6)
Najran	2241	(6.3)
Al Madina Al Monawarah	2123	(6.0)
Northern borders	2044	(5.8)
Hail	1945	(5.5)
Gizan	1613	(4,7)
Qassim	1293	(3.7)
Al Baha	864	(2.5)
Tabuk	715	(2.0)
Total	**35,279**	**(100)**

Table 2 - Age and gender grouping of the children from birth to 5 years.

Decimal age in months	Gender				Total	
	Male		Female			
	n	(%)	n	(%)	n	(%)
Birth	1504	(51.9)	1392	(48.1)	2896	(100)
0.0 - 0.99	213	(49.1)	221	(50.9)	434	(100)
1 - 1.99	225	(49.5)	230	(50.5)	455	(100)
2 - 2.99	301	(51.9)	279	(48.1)	580	(100)
3 - 3.99	255	(50)	255	(50)	510	(100)
4 - 4.99	283	(53.7)	244	(46.3)	527	(100)
5 - 5.99	278	(52.3)	254	(47.7)	532	(100)
6 - 6.99	247	(48.7)	260	(51.3)	507	(100)
7 - 7.99	218	(50.6)	213	(49.4)	431	(100)
8 - 8.99	200	(50.9)	193	(49.1)	393	(100)
9 - 9.99	207	(46.6)	237	(53.4)	444	(100)
10 - 10.99	180	(52.9)	160	(47.1)	340	(100)
11 - 11.99	259	(53.2)	228	(46.8)	487	(100)
12 - 14.99	344	(50.1)	342	(49.9)	686	(100)
15 - 17.99	330	(50.1)	329	(49.9)	659	(100)
18 - 20.99	340	(53.5)	296	(46.5)	636	(100)
21 - 23.99	270	(50.7)	263	(49.3)	533	(100)
24 - 29.99	357	(50.2)	354	(49.8)	711	(100)
30 - 35.99	347	(48.1)	375	(51.9)	722	(100)
36 - 41.99	333	(45.4)	401	(54.6)	734	(100)
42 - 47.99	382	(50.1)	381	(49.9)	763	(100)
48 - 53.99	413	(53.2)	363	(46.8)	776	(100)
54 - 59.99	356	(46.8)	404	(53.2)	760	(100)
Total	**7,842**	**(50.5)**	**7,674**	**(49.5)**	**15,516**	**(100)**

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Table 3 - Age and sex grouping of the children and adolescents from 5-19 years.

Decimal age in years	Gender				Total	
	Male		Female			
	n	(%)	n	(%)	n	(%)
5 -5.99	835	(52.1)	768	(47.9)	1603	(100)
6 - 6.99	759	(51.0)	730	(49.0)	1489	(100)
7 - 7.99	799	(50.6)	779	(49.4)	1578	(100)
8 - 8.99	811	(51.9)	752	(48.1)	1563	(100)
9 - 99	790	(52.2)	724	(47.8)	1514	(100)
10 - 10.99	782	(49.0)	815	(51.0)	1597	(100)
11 - 11.99	761	(51.8)	708	(48.2)	1469	(100)
12 - 12.99	726	(50.6)	709	(49.4)	1435	(100)
13 - 13.99	750	(52.4)	680	(47.6)	1430	(100)
14 - 14.99	720	(51.1)	689	(48.9)	1409	(100)
15 - 15.99	635	(51.0)	609	(49.0)	1244	(100)
16 - 16.99	625	(50.3)	618	(49.7)	1243	(100)
17 - 17.99	523	(49.6)	531	(50.4)	1054	(100)
18 - 18.99	421	(47.0)	475	(53.0)	896	(100)
19 - 19.99	101	(42.3)	138	(57.7)	239	(100)
Total	**10,038**	**(50.8)**	**9,725**	**(49.2)**	**19,763**	**(100)**

gender group). **Figures 1 to 4** (for boys) and **Figures 5 to 8** (for girls), represent the growth charts for children from birth to 36 months showing weight, length, and head circumference for age and weight for length. **Figures 9 to 12** (for boys) and **Figures 13 to 16** (for girls) represent the growth charts of children and adolescents from 2 to 19 years, indicating weight, stature, and head circumference for age and weight for stature. For each chart, a complete range of percentiles including the 3rd, 5th, 10th, 25th, 50th, 75th, 90th, 95th, and 97th were calculated as presented in **Figures 1-16**.

Discussion. The multistage probability random sampling procedure used in this study is the strongest design to select a representative sample of the population. In addition, the protocol of collecting data by house-to-house visits adopted in this study, is more accurate than collection from health centers because of the possiblity of not covering all socioeconomic classes of the population. The finding of 84.8% eligible households indicates an adequate sample and did not affect the needed number of children and adolescents, because of the higher family size than that estimated by the calculated sample size. Similarly, the finding of 73% of the households in urban and 27% in rural settlements indicates adequate urban-rural representation. In addition, the distribution of the type of housing, housing ownership, the education level, and occupation of the head of household, and the pattern of feeding and nutrition in our sample are all comparable to those of the larger Saudi family study,[20] indicating that our study sample is a good representative of our general pediatric population because of its similarities to that reported by a larger family study.

All possible precautions were taken to ensure accuracy of data collection in all steps of the study from its primary design to statistical analysis. The number of selected children from each region is accurately proportional to the population size of relevant region, thus provides adequate representation. The system of age grouping is similar to that used by CDC, and clearly demonstrates that, in most age groups the number of boys and girls far exceeds the minimum number of 200, required for the calculation of growth percentiles.[10]

The LMS methodology used in this study is the most up-to-date, used by the CDC to construct the new 2000 CDC growth charts for the United States,[21] and the WHO to construct their curves for the 2006 WHO Child Growth Standards.[22] The general shape of curves in all charts of this study is similar to that reported by others.[21,23] In general, compared to a previous study, performed approximately 10 years ago on Saudi children under 5 years of age, the growth parameters in our study are shifted upward indicating better growth.[23-25] This finding suggests that the proportion of children with growth deficiency in the current population will be lower if assessed by the previous reference than the current reference. However, compared to the CDC 2000 reference, the growth percentiles in this report are shifted downward.[21] This finding indicates that when Saudi children are assessed by the CDC charts, the proportion of children with growth deficiency will be exagerated. More detailed analysis of our data is underway for more accurate comparison with relevant growth references in the literature.

It is concluded that these growth charts are the most recent, comprehensive, and representative of the Saudi population of children and adolescents. The availability of such reference data should help clinicians practicing in the Kingdom in better assessment of their patients' growth than respective charts of other populations. Accordingly, we recommend these charts to replace the existing older charts and those of other countries in all clinics and hospitals of the Kingdom. Similarly, clinicians practicing in neighboring countries may find these charts more relevent than those derived from more distant populations.

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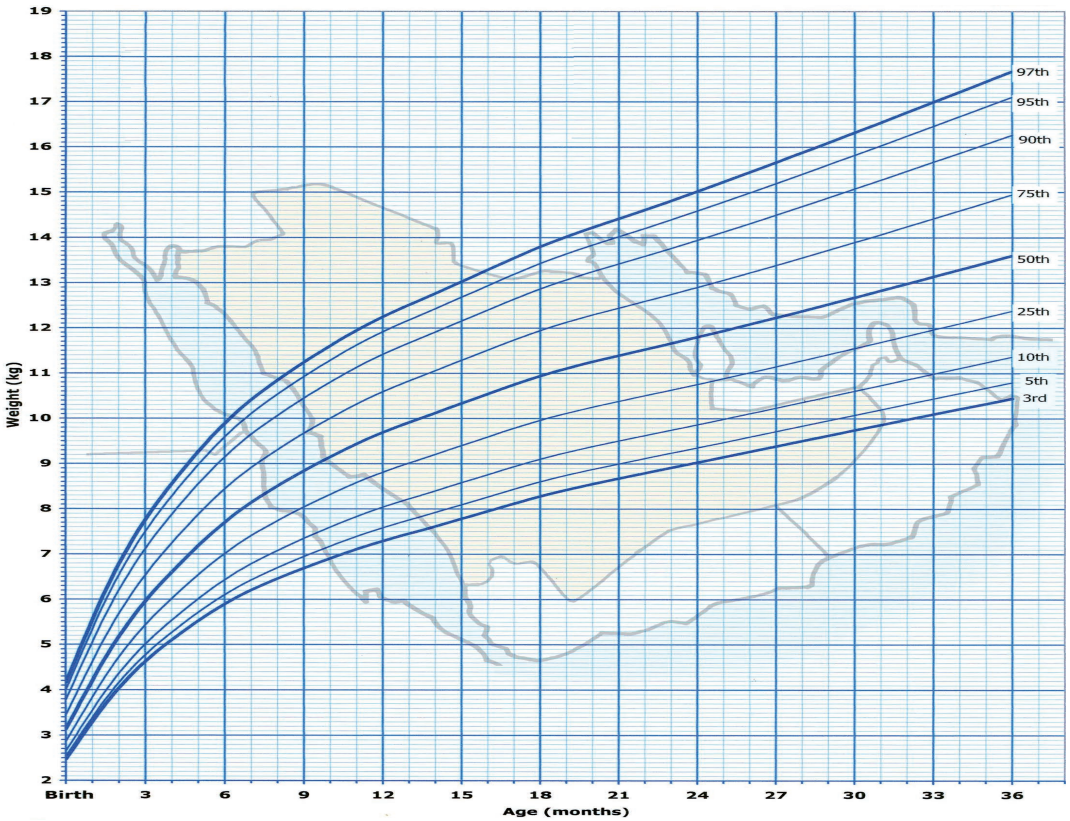

Figure 1 - Weight-for-age percentiles: boys, birth to 36 months.

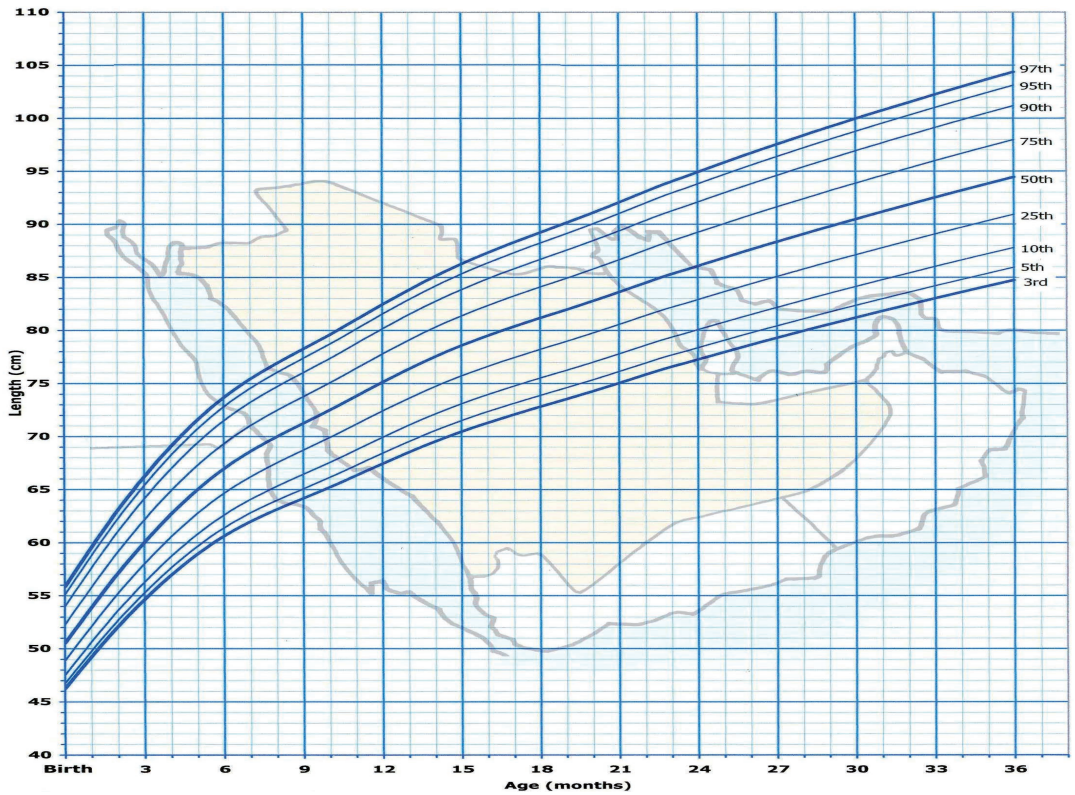

Figure 2 - Length-for-age percentiles: boys, birth to 36 months.

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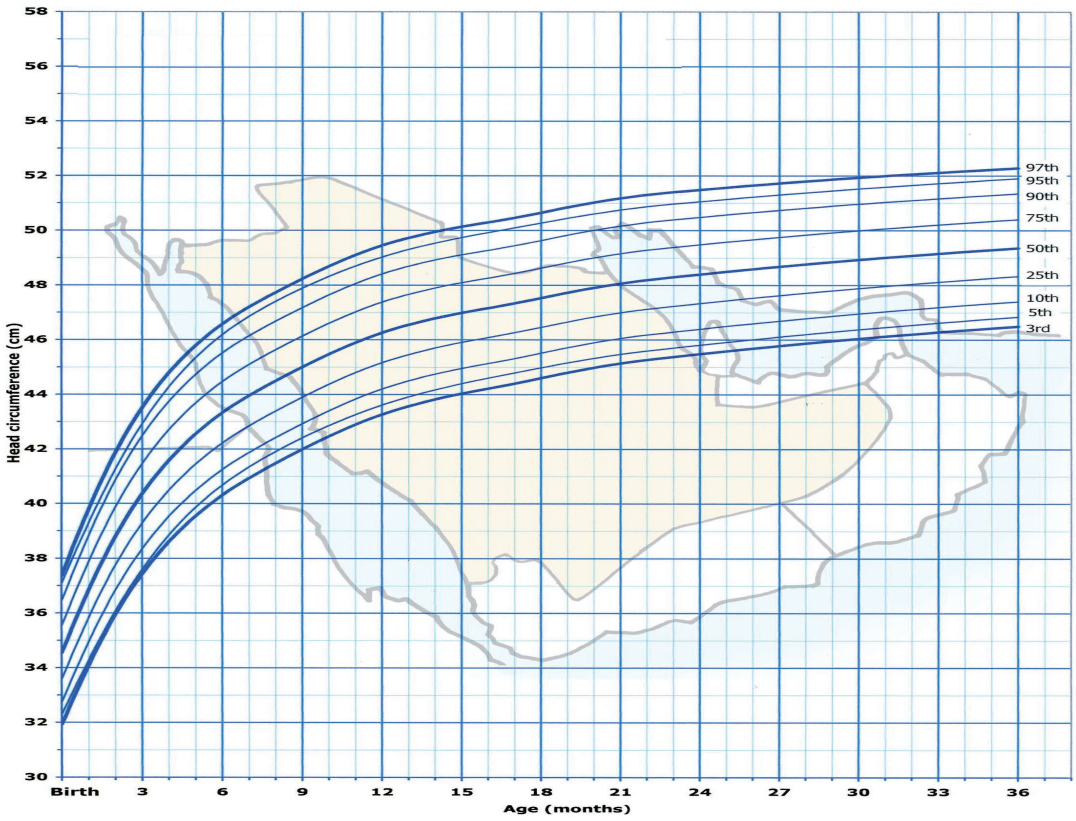

Figure 3 - Head circumference-for-age percentiles: boys, birth to 36 months.

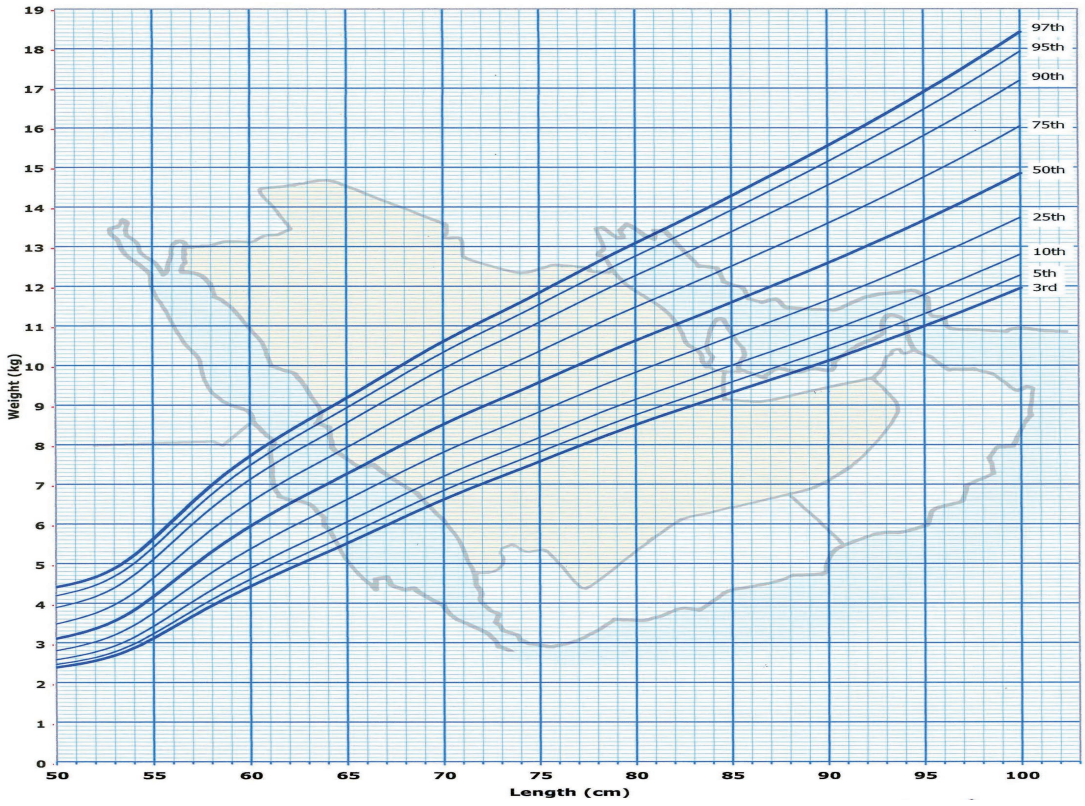

Figure 4 - Weight-for-length percentiles: boys, birth to 36 months.

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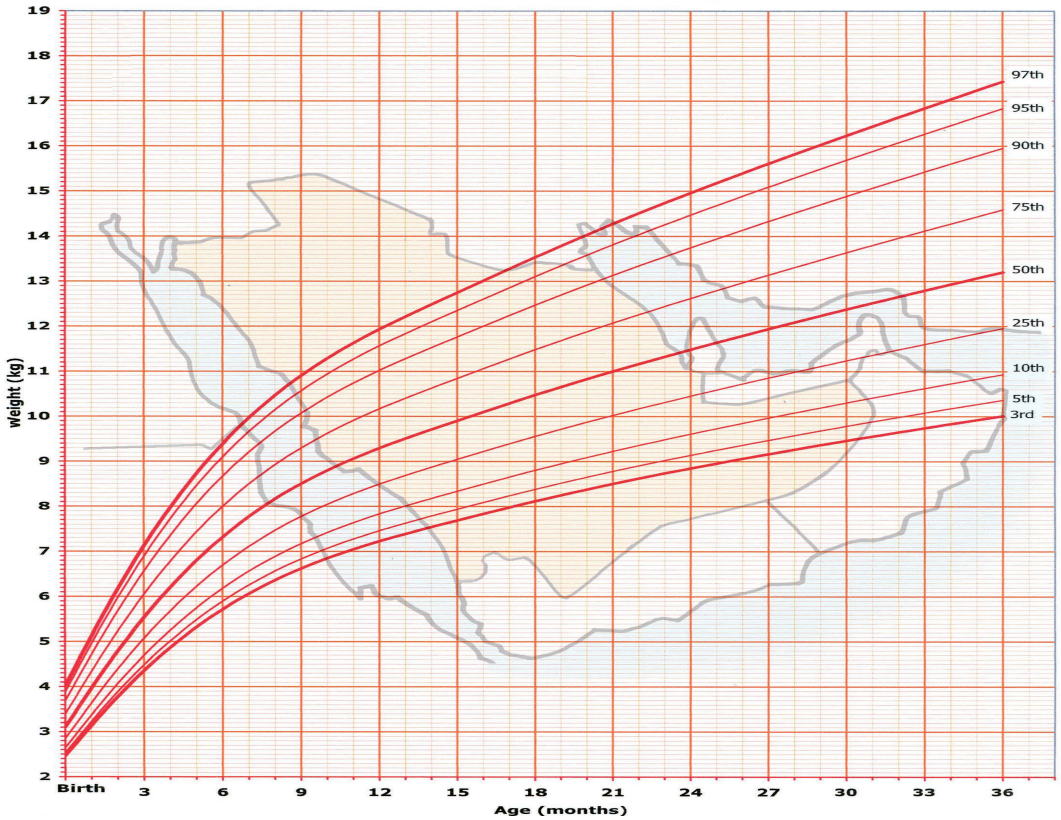

Figure 5 - Weight-for-age percentiles: girls, birth to 36 months.

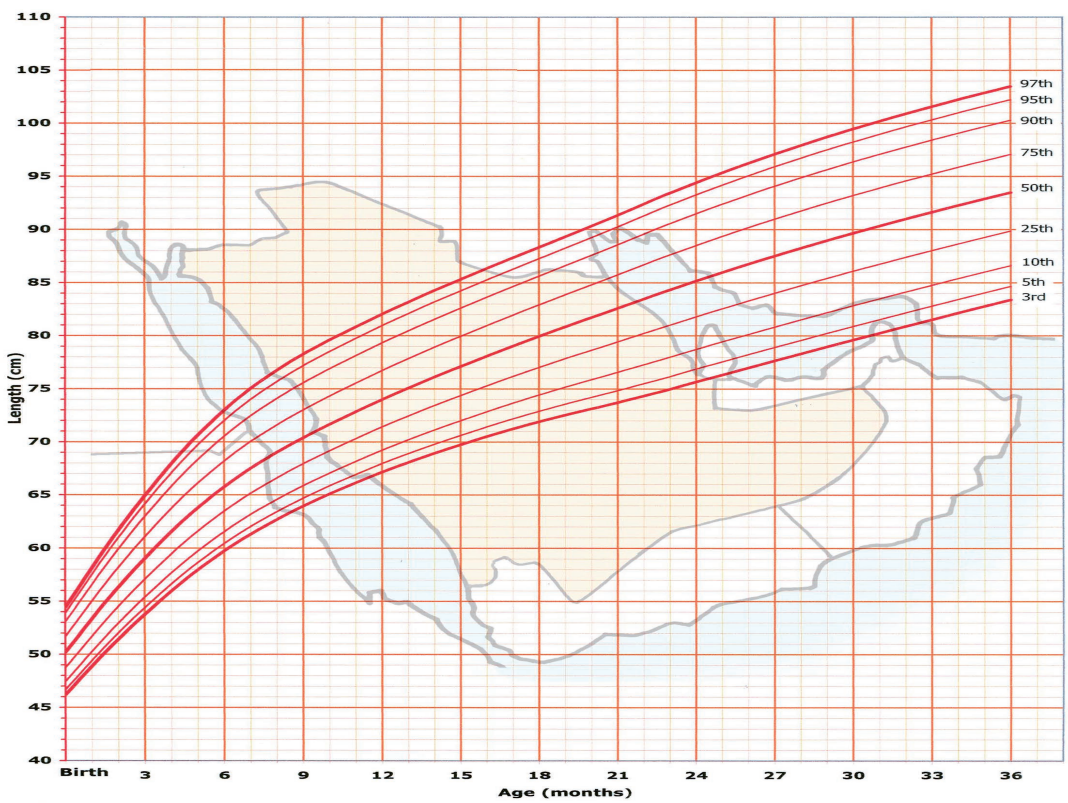

Figure 6 - Length-for-age percentiles: girls, birth to 36 months.

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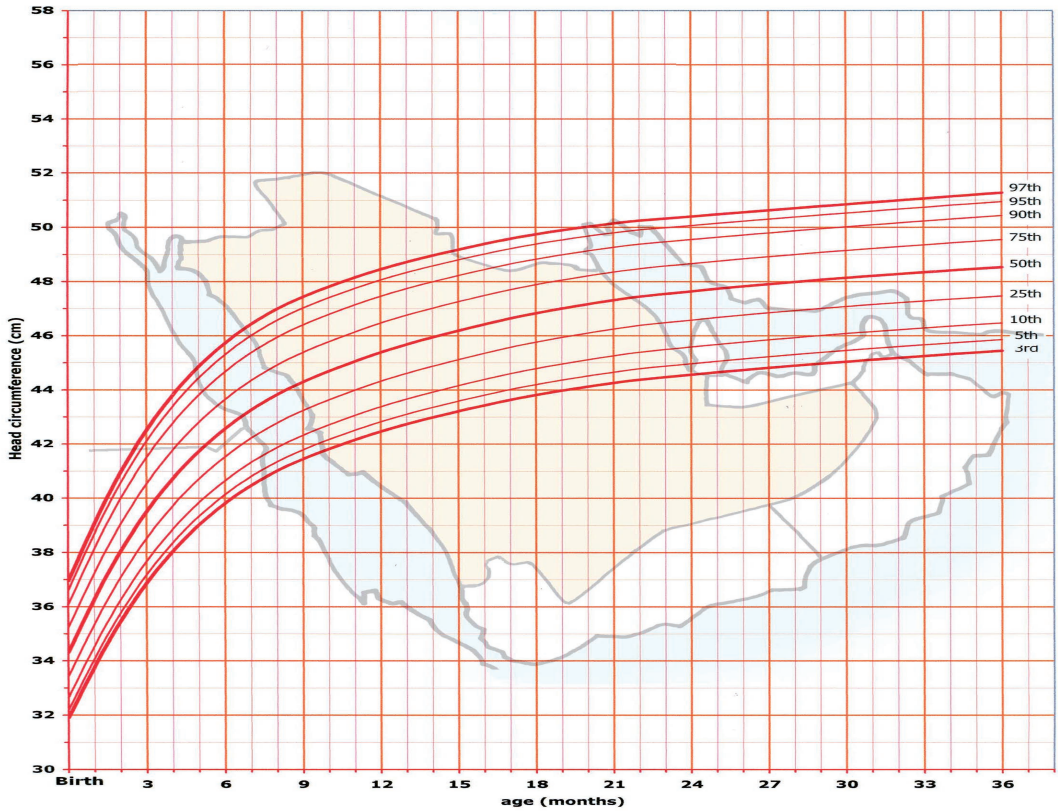

Figure 7 - Head circumference-for-age percentiles: girls, birth to 36 months.

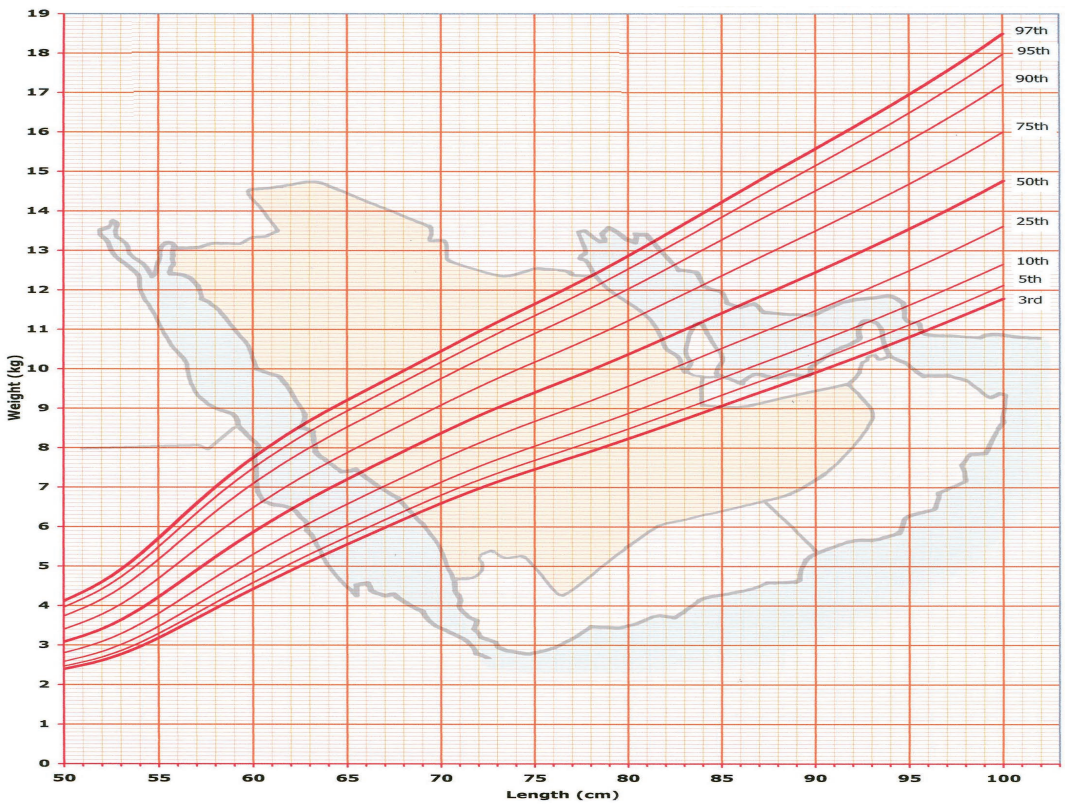

Figure 8 - Weight-for-length percentiles: girls, birth to 36 months.

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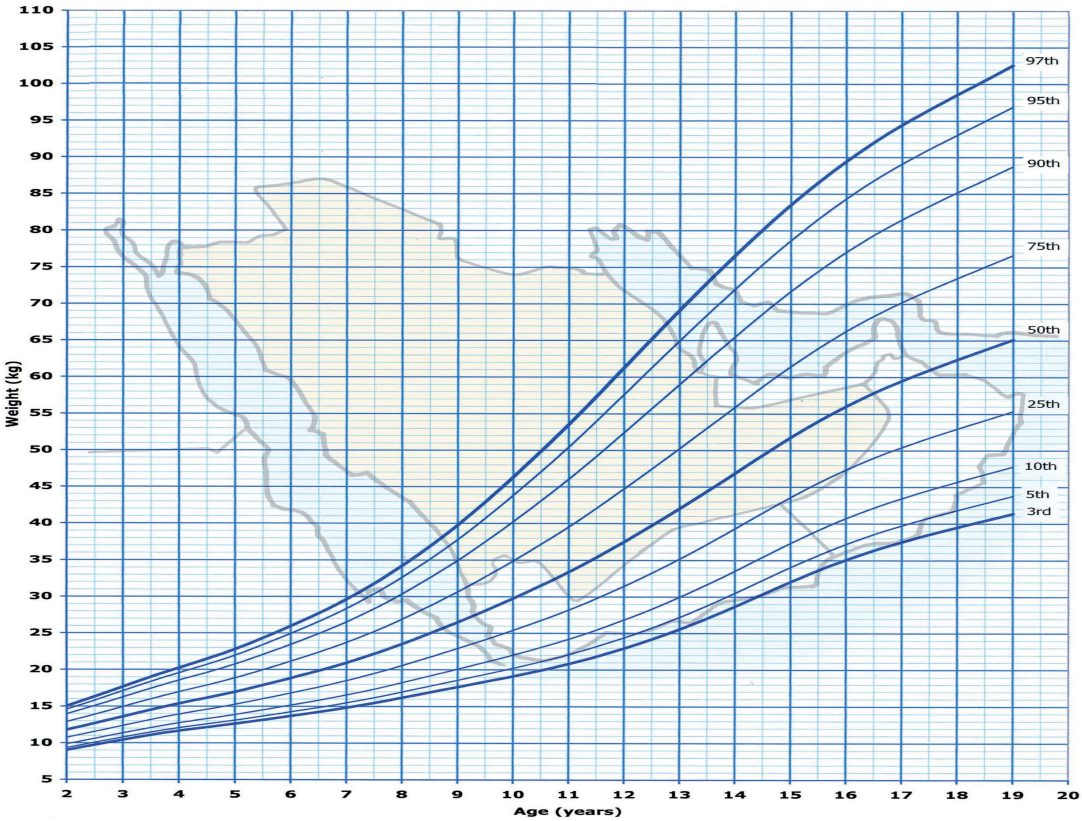

Figure 9 - Weight-for-age percentiles: boys, 2 to 19 years.

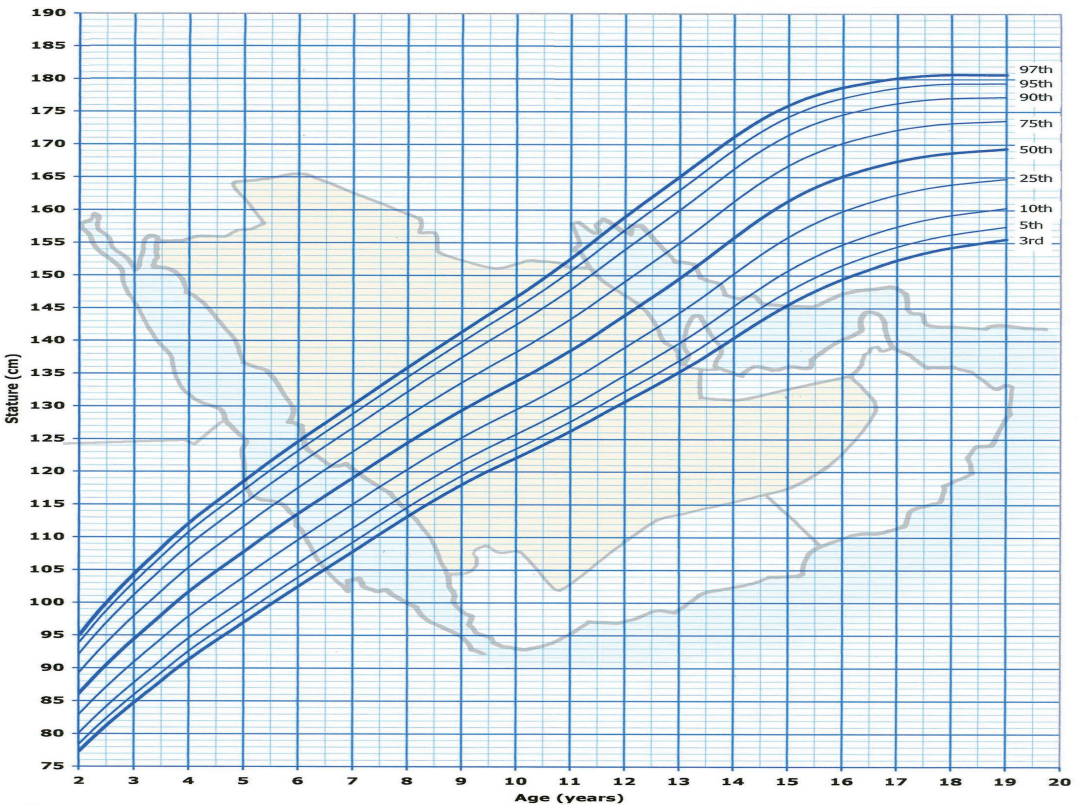

Figure 10 - Stature-for-age percentiles: boys, 2 to 19 years.

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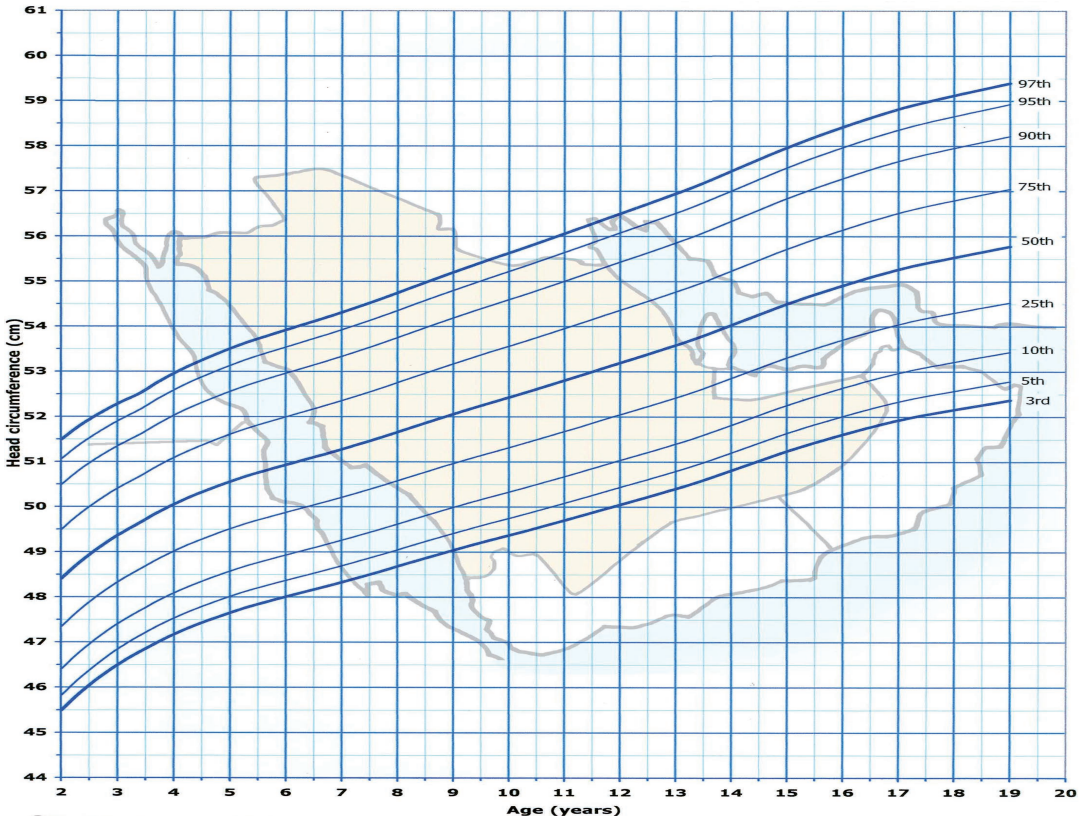

Figure 11 - Head circumference-for-age percentiles: boys, 2 to 19 years.

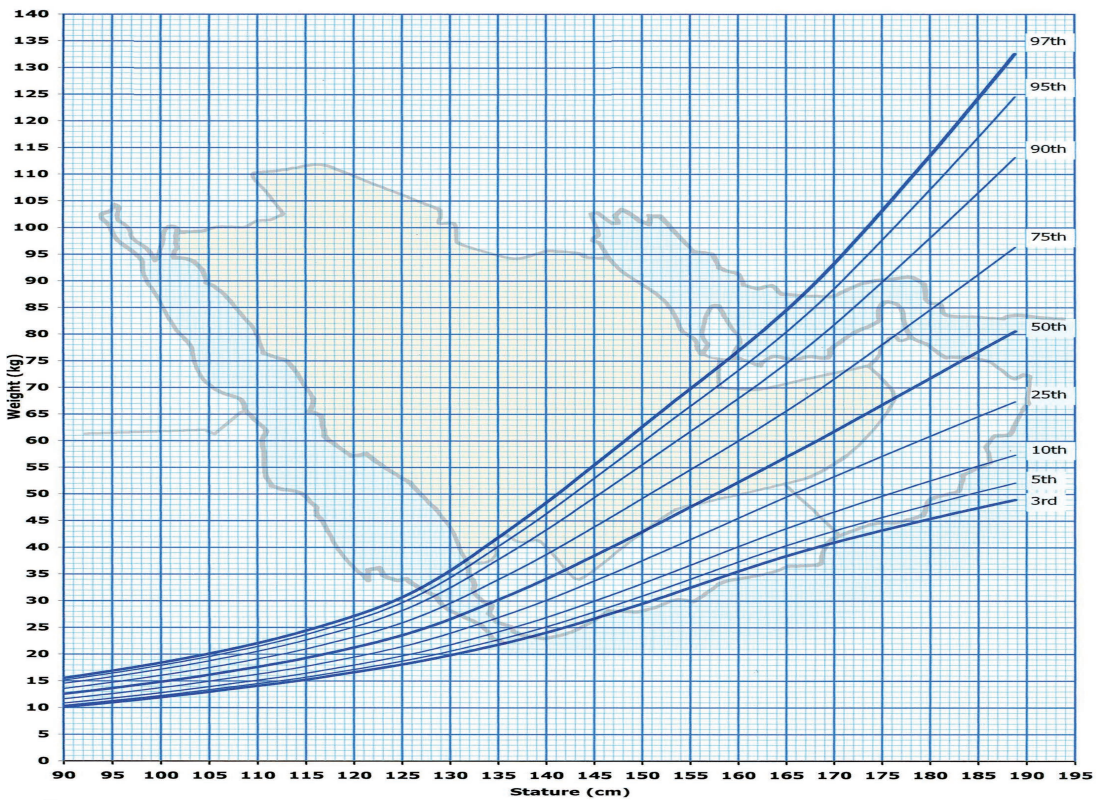

Figure 12 - Weight-for-stature percentiles: boys, 2 to 19 years.

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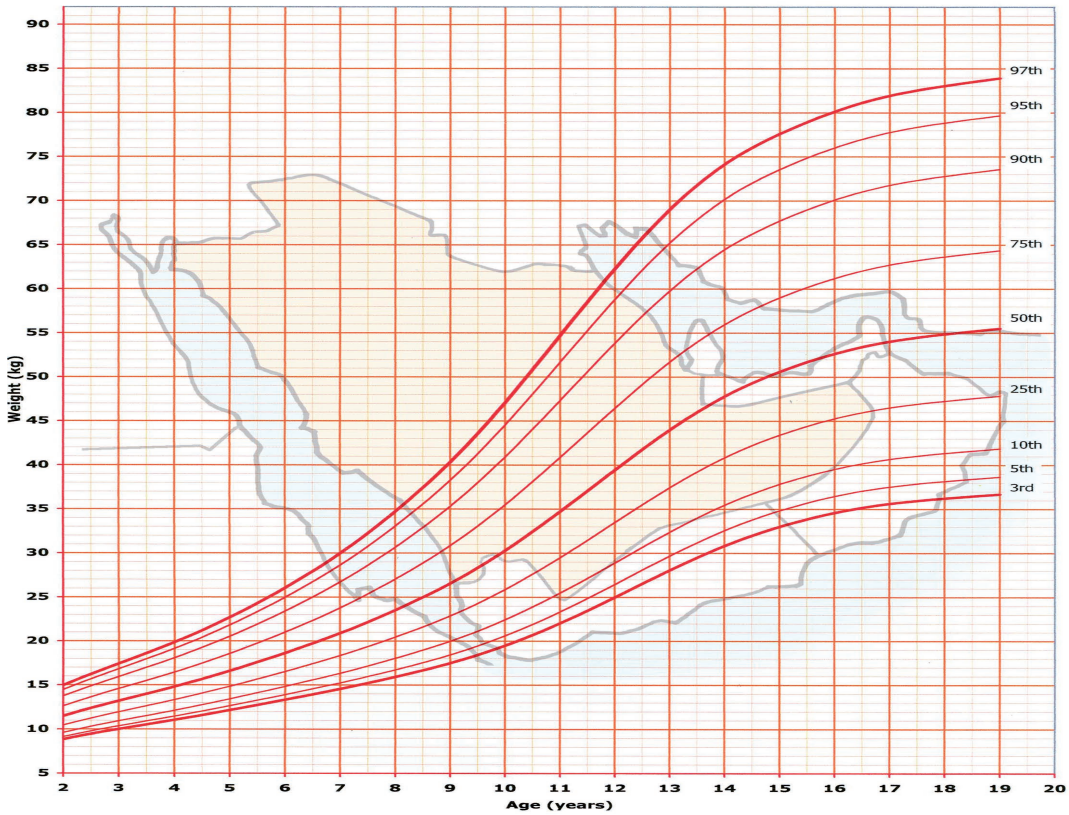

Figure 13 - Weight-for-age percentiles: girls, 2 to 19 years.

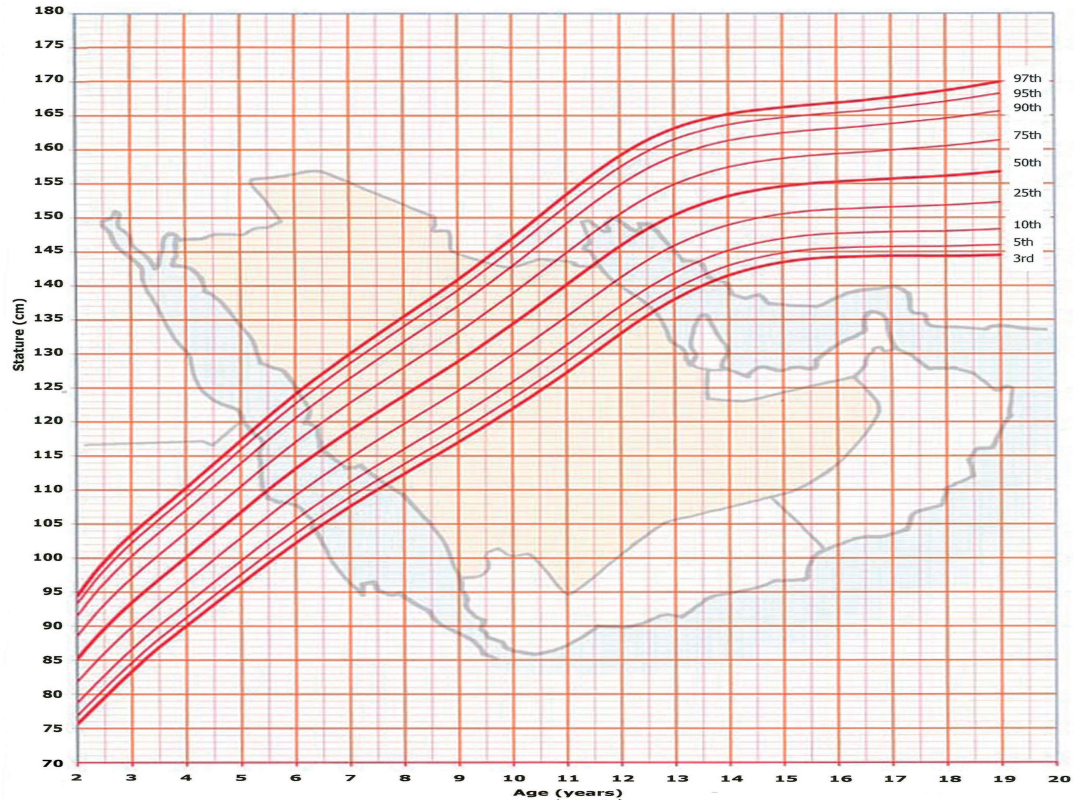

Figure 14 - Stature-for-age percentiles: girls, 2 to 19 years.

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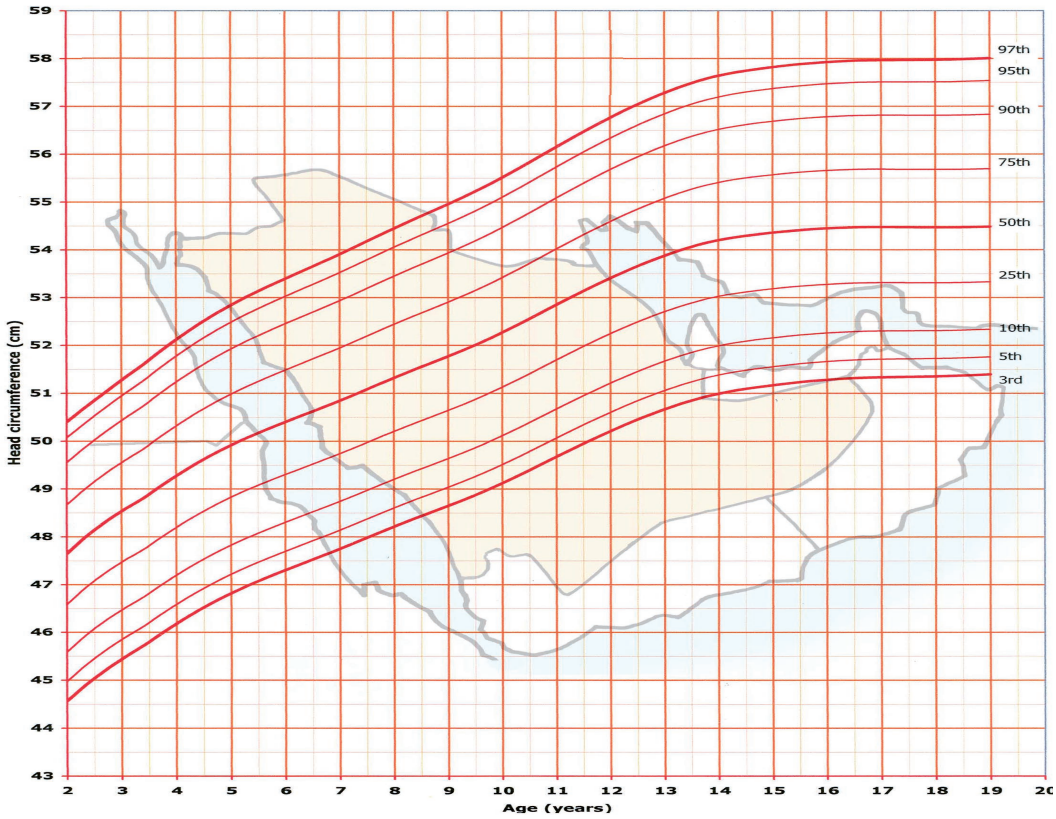

Figure 15 - Head circumference-for-age percentiles: girls, 2 to 19 years.

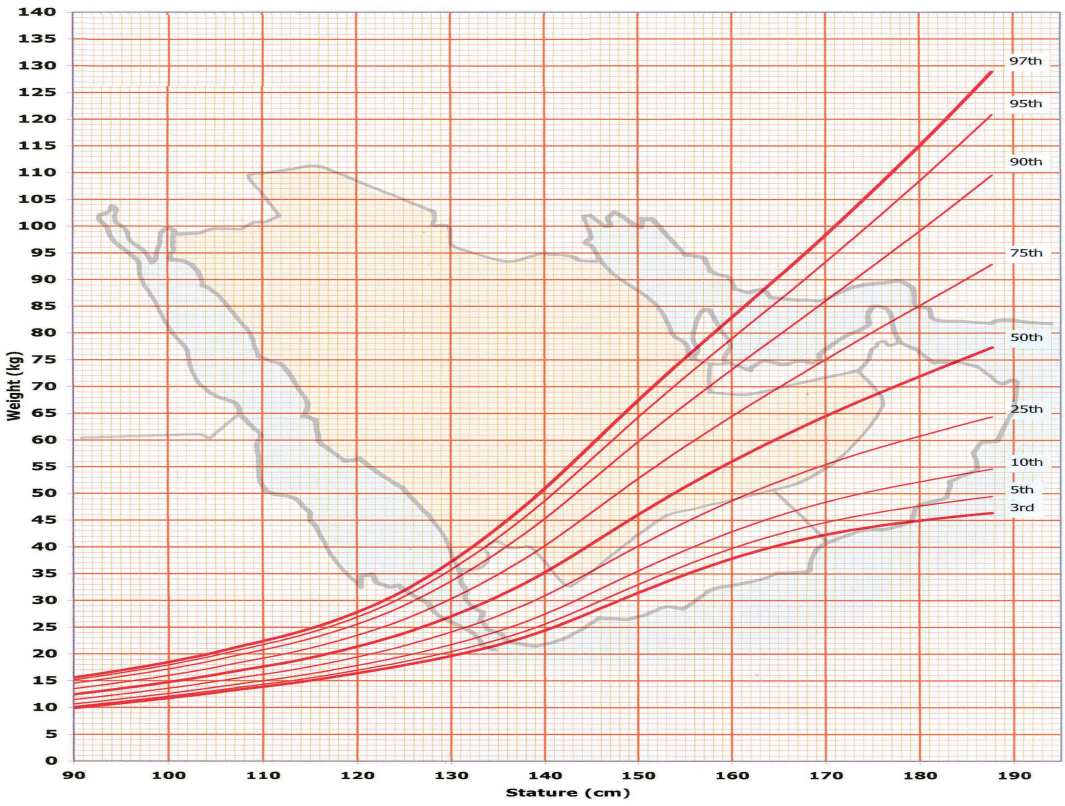

Figure 16 - Weight-for-stature percentiles: girls, 2 to 19 years.

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Ethical Consent

All manuscripts reporting the results of experimental investigations involving human subjects should include a statement confirming that informed consent was obtained from each subject or subject's guardian, after receiving approval of the experimental protocol by a local human ethics committee, or institutional review board. When reporting experiments on animals, authors should indicate whether the institutional and national guide for the care and use of laboratory animals was followed.

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