Evaluation of the growth of children: path of the growth charts

Aline Alves Ferreira[1]

[1] National School of Public Health, Oswaldo Cruz Foundation, Brazil. Rio de Janeiro State University. Rio de Janeiro, RJ, Brazil.

Correspondence
Aline Alves Ferreira
E-mail: aline _ af@yahoo.com.br

Abstract

This paper aims to present and discuss, from the literature review, concepts related to child growth charts, emphasizing historical, methodological and anthropometric aspects. Study databases comprised PubMed, Scopus and SciELO. Manuscripts, technical books, websites, organizations, and national and international organs that addressed this topic in Portuguese, English and Spanish, in the period from 1966 to 2012, were also included. From Guarinoni, Montbeillard and other researchers, the concept of child growth gained more popular contours, especially when it came to how to quantify it and evaluate it through growth curves. Several steps were taken to arrive at current "optimal child growth curve", currently represented by references and growth patterns proposed by WHO in 2006 and 2007. Despite its widespread diffusion among countries and readings, there are critiques and re-adaptations of these curves involving local specificities and age. Faced with the new complex problems in child health in a shorter time can be generated a new proposal for standard and international reference. Paradoxically, it seems that we go little by little towards specificity: each group with its own children's growth curve.

Key words: Growth Charts. Growth. Child. Anthropometry.

Introduction

Somatic growth is a complex, flexible and therefore variable process.[1,2] It is considered one of the best indicators of children's health and nutrition, reflecting the interaction of numerous intrinsic and extrinsic factors. [3]

Anthropometry and the use of tables and figures are resources commonly used to assess child's growth. This process can be summarized graphically from percentiles distributions (or z-scores) of anthropometric measurements of children considered references. Growth curves or charts are then constructed.[3,4]

These tools are used by different healthcare professionals and are considered essential for the evaluation and monitoring of child's health condition both in clinics and in public healthcare services. [3-5] However, the construction of said curves and the search for the best population to represent children's growth passed through several stages until these days.

In this context, this study aims to present and discuss, based on literature review, concepts related to child's growth, with emphasis on the historical, methodological and anthropometric aspects from the standpoint of children's physical growth.

Data sources

This article is based on the major texts that influenced the current concepts on child's growth evaluation and growth curves. A literature survey was undertaken from August 2011 to June 2012, using the Portuguese, Spanish, and English languages. The databases from *PubMed*, *SciELO* and *Scopus* were accessed, using the following combination of descriptors and keywords: *growth charts, children, childhood, growth, body weight, body height, child development e growth references and assessment of growth*. CAPES website was also consulted.

Based on the abstracts, those not matching the topic were excluded, resulting in a total of 47 articles and nine books. Out of these, 34 studies that best fitted the theme of the present study were then selected. Technical books on the subject were also sought in libraries and on websites of national and international organizations and bodies. The publications from the period of 1966 and 2012 were considered.

An historical outlook on the child physical growth and construction of growth charts

Diverse currents and approaches supported studies on human growth in the last centuries and, as a consequence, influenced the construction of child growth curves. One of the most rudimentary studies on child growth was conducted in the sixteenth century. Hippolyt Guarinoni associated the delayed growth of boys to emotional causes, particularly to periods of stress in school. [3]

However, Philibert Guéneau de Montbeillard, in France, conducted the first study addressing the issue systematically and longitudinally. He analyzed the growth of his son from birth (1759) to 1777 in the form of charts and tables, establishing the existence of the pubertal growth spurt and seasonal changes in growth rates. He also confirmed the occurrence of height "shrinkage" in daytime. It can be considered a very refined work for the time, with good accuracy, although lacking robust statistical analysis or the use of sampling techniques.[3,6]

In Europe, in the early nineteenth century, following the Industrial Revolution, a new line of studies on human growth emerged. They consisted of investigations originated from the responses of humanitarian approaches to cope with poverty of workers and their children. Growth data began to be used to define the ideal health conditions and those considered poor, substandard. Surveys on the health of school-aged children and efforts to monitor the nutritional status began to be undertaken.[6]

Regarding Public Health Nutrition, Adolphe Quetelet was one of the most important exponents. He is considered the father of the studies on human growth in the modern age and founder of the modern statistics, introducing the practical application of the normal curve. He was the first to conduct a population (transversal) survey with children in 1831 and 1832, using statistical techniques considered modern for the time and associating the different growth patterns to environmental factors. Influenced by Louis-René Villermé, who two years before had published a work addressing the effects of poverty on the height of French recruits, Quetelet's survey culminated in the publication of the most important study on child's growth patterns: *Sur l'homme et le développement de ses facultés*. He was also responsible for the creation of the index widely used today, relating weight to height - the body mass index (BMI), or Quelet's index.[6]

Meanwhile, anthropometry was consolidated as a method for studies on human growth in the field of public healthcare and was incorporated to the medical practice. The need of comparable data on the patient then emerged. So, the data considered as references began to be collected more seriously and systematically in the nineteenth century, and at the end of this century the first growth charts were developed. [1,6]

From the studies by James Mourilyan Tanner in the late nineteenth century and early twentieth century and the creation of the Human Growth Service in England, growth analysis began to have a broader approach, being defined as a set of physicochemical, morphological and genetic cell phenomena. Environment began to be considered a key modifier factor. The growth concept gained more popular contours among the scholars of the time, especially with regard to the ways of quantifying and assessing it. Growth velocity references and growth charts then began to be disseminated.[3,7]

The path to the current child growth references and standards

Growth accurate assessment has been a matter of concern of the diverse areas of public healthcare and human biology for decades. Anthropometry, the most widely used method to evaluate the nutritional status[4], provides data that can be compared with those from populations considered references, i.e., healthy individuals who live in social, environmental and economic conditions that are ideal for a good development. The synthesis of such individuals' anthropometric values constitute a growth reference, expressed graphically (growth curves) or in tables.[8]

The growth curves are built from longitudinal or transversal data. They show the relations between anthropometric and demographic variables, such as, for example, weight and age, by means of a single summarized curve, expressed as percentiles or z-scores. The graph is represented by one or more lines that grow progressively, with gradual increments of anthropometric measurements, according to sex and age, starting from birth.[8]

They can be considered versatile and important technical tools for the measurement, monitoring and evaluation of children's growth, either individually or collectively. They are widely used in the clinical practice by diverse healthcare professionals to monitor the child individually and also as a tool in public healthcare, to summarize and compare anthropometrically groups of children. It has been considered a very sensitive indicator of the child's overall health, allowing specific interventions and the prevention of health impairments. [7,9]

And what reference population should be used to assess a child's growth? This question has received special attention in the past decades. Discussions about the development of universal or specific curves for certain populations appeared even earlier. Regardless the type of curve, the key objective was to build a parameter that would show an ideal growth. [3,7]

Some authors have advocated the construction of local charts from national or specific references for certain groups of population. They argued that there was influence of genetic and ethnic

factors on the children's development and growth, including the first years of life. [2] Conversely, others claimed that these factors, until the fifth year of life were less important than the environmental conditions to which the child was exposed. Therefore, growth until this age would be universal for any population that could be considered healthy.[9]

Assuming that growth charts from populations considered references could be satisfactorily applied to every child in the world, a single child growth chart began to be built. [9] There were numerous attempts to develop internationally oriented curves. One of the first was Iowa's chart in the United Stated. Based on the longitudinal study that was initiated in the first half of the twentieth century (*Iowa Child Welfare Study*), comprising white children, growth curves were built. Soon these data showed not to be universal and suitable for being applied to other populations.[10]

The first reference chart most used worldwide and recommended by WHO was the Harvard growth curve (USA). Comprised of transversal studies (between 1930-1956) with U.S. Caucasian children from Boston, it had weight-for-age, height-for-age, and weight-for-height indexes for infants under 36 months of age of both sexes, and the two first indexes for children from two to 18 years of age. It was widely used by pediatricians at the time and its biggest weakness lay on the fact that the sample was not nationally representative. [8,10]

A growth standard, the Gómez's classification, was more disseminated in the international context than Harvard growth curves, particularly in Pan-American countries.[10] It is worth noting that in theoretical terms there is a key difference between the terms "standard" and "reference". The first covers the notion of a normative or desirable goal, involving a value judgment. The second is defined as a tool for data gathering and analysis, providing a common basis for comparing populations, without inferences on the significance of the differences observed. The reference data may incorporate some characteristics or normality standards and, as a result, be used to make inferences on the health and/or nutritional status of individuals and populations.[3,10] Gómez's growth standard has not only influenced numerous attempts of standardization but also the construction of local growth charts in less developed countries, including Brazil. In the 1960s and 1970s, Eduardo Marcondes developed growth charts in the country by means of two transversal studies with individuals from 0 to 20 years of age, having high socioeconomic status, in the city of Santo André, SP.[11] Besides using non-robust methodologies it was not validated externally and was not representative of the Brazilian population. [8]

In the same period, Tanner et al.[12] developed curves for the growth velocity from a sample of British children from the Centre of Child Studies (currently Centre for the Study of Human Development) who were followed since birth. The concept of velocity applied graphically was a novelty at the time but for reasons similar to the methodology of the Harvard growth curves, it was not divulged internationally. [10]

In the late 1970s, WHO disclosed a reference with national representativeness which later was also accepted as a new growth standard: the growth chart of the *National Center for Health Statistics* – NCHS.[10] Since then, many countries began to use the same reference, allowing comparisons between several regions in the world. The NCHS growth chart was built from two longitudinal studies on the U.S. population[13,14]: one with children under two years of age (between 1929 and 1975); and another for the other children, up to 18 years of age (between 1960 and 1975). One of the limitations was its use for adolescents (older than 10 years): the NCHS curves covered 18 years only and not adolescents under 20, as the period of adolescence is usually considered. In addition, the sampling size varied in different ages, and the mean ages differences of puberty occurrence were not taken into consideration in the various ethnic American groups.[5]

From the late 1980s, more severe critiques on the limits of the percentiles used and inappropriate statistical procedures to describe the growth standard and variability began to appear. Thus, in 2000, NCHS published a new reference developed by the *Center for Disease Control and Prevention* (CDC), including 14% of young blacks in the sample. The data were collected from five studies conducted from 1963 to 1994. In addition to different indexes for all ages, BMI-for-age was also incorporated.[15] But children with low birth weight were not included, not necessarily being exclusively breastfed, and the baseline population continued to be the United States. [16]

After a comprehensive review on the use and interpretation of the growth chart proposed by NCHS, in 1993 experts concluded that this reference was not appropriate to evaluate and monitor the growth of children in all parts of the world. So, plans and actions were undertaken, resulting in the new WHO growth chart published in 2006 and 2007. [17,18]

The new who growth chart: just the current recommendation or have we reached consensus?

Today, it is recommended the use of the international growth patterns and references published by WHO in 2006 and 2007. More than 140 countries, including the least economically favored nations, are currently in the process of implementing such curves. [19] WHO charts show important differences in relation to the references previously used, particularly the NCHS references.[13,14] A multidisciplinary team conducted a multicenter hybrid study with more than 8,500 young children from different ethnic groups and nations living in environmental conditions considered optimal for growth. Among the innovative aspects, the study included the growth velocity graph, the relation between physical and motor development, and definition of breastfeeding as a parameter for ideal growth. An important change was the inclusion of BMI-for-age parameter and the exclusion of the weight-for-height index from the medical practice. [17,18]

The new curves can detect better any failure in the growth process, enabling early interventions, and are more sensitive to overweight and obesity, the main nutritional problem nowadays. It is considered technically a more robust tool, being not just a reference but also a new international standard.[16,19]

Apparently, the new WHO growth curves solved the main issues concerning the methodology of the references used previously and have been recommended for assessing the ideal growth pattern of children and adolescents. Its applicability is based on the assumption of a low influence of genetic variability in children's growth potential when compared to the environmental variability. So, when exposed to ideal conditions, children, regardless their origins, grow equally.

Due to the recent publication, there still is a transition process in the use of the new chart. Its international applicability is questioned with respect to certain groups, such as the much lower height than the current standard of the pygmies in Central Africa or the "ianomâmis" in Brazil. [20] According to Waterlow,[20] there are innate genetic differences between different ethnic groups, with direct impact on the final height of adult individuals. However, it seems today that the general opinion is that there are no significant differences in the growth potential between different ethnic groups, and, if so, they are minor differences.

The exclusive use of the new charts to assess the nutritional status in some ethnic groups is also discussed. The key issue would not be its validity, but the difficulties of comparison, especially because of the impossibility of re-analyses of some data and comparability of prevalence of malnutrition.[21,22] Re-evaluations of the results of nutritional status of previous studies will still be necessary as well as how to explore the use and functional validity of the standards, mainly the indicators that were not available before.[16]

Some publications, after 2006, have presented comparisons of national references with the WHO growth references, not always agreeing with the new standards. Examples are countries such as South Africa, United Arab Emirates, Poland, Hong Kong, Iran, Norway, Germany, and United Kingdom.[21,23-30] In other cases, such as in UK, the WHO curves were blended with the local curves at certain phases of childhood.[14] Other countries, such as China, Denmark, Belgium, Czechoslovakia, Bolivia and Norway, have expressed reservations regarding the use of the new curves, because investigations have shown that the children growth in these locations are significantly different from the parameters proposed by WHO. So they decided to continue using their own population-based graphs as reference of child growth.[19]

For some authors, regular updates of local references and comparisons with the WHO growth chart based on multicenter national studies would provide important information on the local children's growth, and greater specificity for the diagnosis of the nutritional

status in certain ethnic groups[23,27,38] Others justify the creation of local growth curves based on the fact that, although the WHO curves have representative samples of six continents, these could not be applied to certain countries because of the cultural and socio-economic differences and the influence of genetic factors.[23,25-28,30] Going further, some recommend its use for children being exclusively breastfed in the first months of life, considering the significant differences of the anthropometric parameters between the WHO reference and others.[31]

Moreover, the literature has shown that growth until the age of five has low genetic influence.[3,5,7,8,10] The use of local curves has not been encouraged by key organizations and institutions worldwide because of technical and political difficulties. They present distinct methodological and financial constraints regarding the selection of the representative reference population. It is also believed that the curves built from populations in less developed countries exposed to poor health and nutrition conditions would have a lower screening value when determining malnutrition.[8,10,19]

The search for the so-called "ideal curve of child growth" may have decreased periodically after the publication of the WHO references in 2006 and 2007, although reviews, criticisms, and re-adaptations of these curves have been accomplished, involving local specificities of some countries. Despite this, no stricter criticism has been produced yet, thus the importance of the new curves is still recognized, especially in the light of its use in international settings.

The future

New complex problems emerged in the late past century. Distinct kinds of environmental stress, including (re)emergent diseases, changes in eating patterns and new lifestyles have caused important impacts on children's growth. New demands and discussions on population studies have arisen, either locally or globally.

Researches involving child growth and development are in transition, from descriptive to analytical. A population description by itself has lost its meaning. The need of significant *p*-values from causal inferences is real. Although many descriptions are adequate and necessary for certain types of public healthcare interventions, there are numerous uncertainties, particularly in understanding the health-disease process associated with children's growth. So, there is an increasing urge to understand and, particularly, develop mechanisms associated with children's growth in different levels: endocrine, immunological, socioeconomic, and genetic.

However analytical strategies need to be incorporated to child's growth, the most consolidated, versatile, low cost and of rapid diagnosis instrument that we have today are the growth charts. Even though with inherent limitations, they provide a single set of references that allow comparison of

data from different groups around the world. The populations that are and still will be used to construct such graphs will still be questioned.

With the emergence and need of longitudinal studies for the public healthcare, in an interval of time shorter than the NCHS and WHO charts, a new proposal for an international standard and reference can be generated. More specific curves for the various stages of childhood have been developed [31] according to the birth weight [32] and intrauterine growth.[33] Although in the opposite direction of the demand for a single international instrument, we are moving at a slower and discrepant pace towards specificity: each country with its own child growth chart.

Final considerations

Physical growth in childhood is one of the most complex events that occur in human life. Quantitative evaluation of this process was the focus of numerous researchers over the centuries, and anthropometry, due to its facilities and relative accuracy, has been consolidated as one of the most important methods for growth assessment.

Over the past 200 years, growth charts have developed considerably. They represent a remarkable synthesis of the children physical growth. The influence of the environment in which a child lives seems to be greater than the genetic and ethnic influence. Thus, several attempts have led to the construction of an international growth reference.

Nowadays, WHO growth curves are recommended to be used by any society, regardless the ethnic background and socioeconomic condition. Among its innovative aspects, it can be highlighted the fact that they originate from a multicenter study, with a sample of children who were exclusively breastfed. They also have growth velocity curves in addition to the relation between the physical and motor development.

The new WHO chart has been very useful, providing a single set of growth references and standards that allow comparisons of data from different populations. However, tests and comparisons with local populations and specific ethnic groups have been shown in literature. Several countries have adopted the new growth chart, but some have questioned its use, also suggesting the use of local references. Questions relating to sampling also began to appear. Updates of such sample data will be crucial over time, particularly if examined in the light of the fast changes in modern lifestyles, in the health-disease process and eating patterns of these children. However, because of all advantages already presented and the methodological care involved in its construction and analysis, the WHO child growth chart is the best tool that we have today. And maybe the best that we will have for some time.

References

1. Bogin B. Patterns of Human Growth. Cambridge: Cambridge University Press; 1988.
2. Tanner JM. Fetus into man: physical growth from conception to maturity. Revised ed. Cambridge: Harvard University Press; 1989.
3. Ulijaszek SJ, Johnston FE, Preece MA. The Cambridge encyclopedia of human growth and development. Cambridge: Cambridge University Press; 1998.
4. Gibson RS. Principles of Nutritional Assessment. Oxford: Oxford University Press; 1990.
5. World Health Organization. Physical status: the use and interpretation of anthropometry. Report of a WHO Expert Committee. World Health Organ Tech Rep Ser. 1995;(854):1-452.
6. Tanner JM. A history of the study of human growth. Cambridge: Cambridge University Press; 1981.
7. Eveleth PB, Tanner JM. Worldwide variation in human growth. Cambridge: Cambridge University Press; 1990.
8. Onis M, Habitch JP. Anthropometric reference data for international use: recommendations from a World Health Organization Expert Committee. Am J Clin Nutr. 1996;(64):650-8.
9. Habicht JP et al. Height and weight standards for preschool children: how relevant are ethnic differences in growth potential? Lancet. 1974;1(7.858):611-4.
10. Onis M, Yip R. The WHO growth chart: historical considerations and current scientific issues. In: Porrini M, Walter P, Editors. Nutrition in Pregnancy and Growth. Bibl Nutr Dieta. 1996;(53):74-89.
11. Marcondes E. Normas para o diagnóstico e a classificação dos distúrbios do crescimento e da nutrição – última versão. Pediatria (São Paulo). 1982;(4):307-26.
12. Tanner JM, Whitehouse RH, Takaishi M. Standards from Birth to Maturity for Height, Weight, Height Velocity, and Weight Velocity: British Children, I965 - Part I and II. Arch Dis Child. 1966;41(454):1-18.
13. Hamill PV et al. NCHS growth curves for children birth-18 years: United States.Vital Health Stat. 1977;(165):1-74.
14. Hamill PV et al. Physical growth: National Center for Health Statistics percentiles.Am J Clin Nutr. 1979;32(3):607-29.
15. Kuczmarski RJ et al. CDC growth charts for the United States: methods and development. Vital Health Stat., 2002;(246):1-190.
16. Van Den Broeck J, Willie D, Younger N. The World Health Organization child growth standards: expected implications for clinical and epidemiological research. Eur J Pediatr. 2009;168(2):247-51.
17. World Health Organization. WHO child growth standards: methods and development. Length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age. 2006 [Acesso em 2012 abr. 20]. Disponível em: <http://www.who.int/entity/childgrowth/standards/Technical_report.pdf>

18. Onis M et al. Development of a WHO growth reference for school-aged children and adolescents. Bull World Health Organ. 2007;(85):660-7.

19. Rao S, Simmer K. World Health Organization growth charts for monitoring the growth of Australian children: time to begin the debate. J Paediatr Child Health. 2012;48(2):E84-90.

20. Waterlow JC. Reflections on stunting. 2011 [acesso em 2011 set 02];(1):1-8. Disponível em: <http://www.smith-gordon-publishing.com/pdf/Chapter-1-Reflections on-stunting-JC-Waterlow.pdf >

21. Norris SA et al. Implications of adopting the WHO 2006 Child Growth Standards: Case study from urban South Africa, the Birth to Twenty cohort. Ann Hum Biol. 2009;36(1):21-7.

22. Orellana JDY et al. Morbidade hospitalar em crianças indígenas Suruí menores de dez anos, Rondônia, Brasil: 2000 a 2004. Rev Bras Saude Mater Infant. 2007;7(3):281-7.

23. Abdulrazzaq YM, Moussa MA, Nagelkerke N. National Growth Charts for the United Arab Emirates. J Epidemiol. 2008;18(6):295-303.

24. Cole TJ et al. Designing the new UK-WHO growth charts to enhance assessment of growth around birth. Arch Dis Child Fetal Neonatal Ed. 2012;97(3):F219-F222.

25. Heydari S, Emamghoreishi F, Amini M. Infants' Growth Charts in Jahrom, Iran. Iran J Pediatr. 2009;19(1):25-34.

26. Hui LL et al. Are universal standards for optimal infant growth appropriate? Evidence from a Hong Kong Chinese birth cohort. Arch Dis Child. 2008;93(7):561-5.

27. Júlíusson PB et al. Growth charts for Norwegian children. Tidsskr Nor Laegeforen. 2009;129(4):281-6.

28. Kulaga Z et al. Polish 2010 growth references for school-aged children and adolescents. Eur J Pediatr. 2011;170(5):599-609.

29. Wright C et al. Implications of adopting the WHO 2006 Child Growth Standard in the UK: two prospective cohort studies. Arch Dis Child. 2008;93:566–9.

30. Rosario AS, Schienkiewitz A, Neuhauser H. German height references for children aged 0 under 18 years compared to WHO and CDC growth charts. Ann Hum Biol. 2011;38(2):121-30.

31. Bertino E et al. Neonatal growth charts. J Matern Fetal Med. 2012;25(supl. 1):67-9.

32. Sherry B et al. Evaluation of and recommendations for growth references for very low birth weight (< or =1500 grams) infants in the United States. Pediatrics. 2003;111(4):750-8.

33. Brock RS, Falcão MC. Avaliação nutricional do recém-nascido: limitações dos métodos atuais e novas perspectivas. Rev paul pediatr. 2008;26(1):70-6.

Submitted: 9/13/2012
Accepted: 11/30/2012