Evaluation of the Feasibility of International Growth Standards for School-Aged Children and Adolescents[1]

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Abstract

The development of an international growth standard for the screening, surveillance, and monitoring of school-aged children and adolescents has been motivated by 2 contemporaneous events, the global surge in childhood obesity and the release of a new international growth standard for infants and preschool children by the WHO. If a prescriptive approach analogous to that taken by WHO for younger children is to be adopted for school-aged children and adolescents, several issues need to be addressed regarding the universality of growth potential across populations and the definition of optimal growth in children and adolescents. A working group of experts in growth and development and representatives from international organizations concluded that subpopulations exhibit similar patterns of growth when exposed to similar external conditioners of growth. However, based on available data, we cannot rule out that observed differences in linear growth across ethnic groups reflect true differences in genetic potential rather than environmental influences. Therefore, the sampling frame for the development of an international growth standard for children and adolescents must include multiethnic sampling strategies designed to capture the variation in human growth patterns. A single international growth standard for school-aged children and adolescents could be developed with careful consideration of the population and individual selection criteria, study design, sample size, measurements, and statistical modeling of primary growth and secondary ancillary data. The working group agreed that existing growth references for school-aged children and adolescents have shortcomings, particularly for assessing obesity, and that appropriate growth standards for these age groups should be developed for clinical and public health applications. J. Nutr. 137: 153–157, 2007.

Introduction

The development of an international growth standard for the screening, surveillance and monitoring of school-aged children and adolescents has been motivated by 2 contemporaneous events, the global surge in childhood obesity (1) and the release of a new international growth standard for infants and preschool children by the WHO in collaboration with the United Nations University (UNU) and other UN agencies, governments, and nongovernmental organizations (2). Recognition of the limitations of existing growth references that are used for assessing childhood obesity [e.g., the National Center for Health Statistics (NCHS)/WHO growth reference (3), the CDC 2000 growth charts (4), and International Obesity Task Force (IOTF) cutoffs (5)] has created an urgency and desirability of harmonizing growth assessment tools conceptually and pragmatically. The new growth standard for infants and toddlers was developed from the WHO Multicentre Growth Reference Study (MGRS) and was released in April, 2006. The MGRS was designed to describe how children should grow rather than how they grew in a particular time and place (6,7). In part, the prescriptive approach upon which the new standard was based required an expanded definition of "health," one that went beyond the absence of overt disease to the adoption of lifestyle practices that support optimal growth and development. If a prescriptive approach analogous to that taken by WHO and UNU for younger children is to be adopted for the development of a growth standard for school-aged children and adolescents, several issues would have to be addressed regarding the universality of growth potential across populations and the characteristics of children and adolescents most likely to exhibit optimal growth.

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Methods

This article reviews the feasibility of developing a single international growth standard with height, weight, and BMI as primary measures for school-aged children and adolescents. A meeting was convened in Geneva, Switzerland, on 16–19 January 2006, by the UNU Food and Nutrition Program, in collaboration with WHO Department of Nutrition for Health and Development and the Food and Agriculture Organization (FAO) Food and Nutrition Division, to present and discuss 11 position papers addressing theoretical, biological, and pragmatic issues pertaining to the development of an international growth standard for school-aged children and adolescents (8–18). In addition to the authors, representatives from WHO, CDC, UNU, FAO, World Food Program (WFP), United Nations Children's Fund (UNICEF), IOTF, and International Association for Study of Obesity (IASO) attended.

To develop a growth standard for school-aged children and adolescents, 2 fundamental scientific questions needed to be addressed and were the focus of the 11 commissioned papers and proceedings of the Geneva meeting. The first question addressed whether it was possible to develop a single international growth standard for children >5 y of age that would be representative and useful for the global population, given the possible genetic differences in growth potential across populations. The second question was whether a prescriptive approach could be used to develop a growth standard for school-aged children and adolescents from either historical and/or prospective growth data.

To address the feasibility of adopting a prescriptive approach to developing a new international growth standard for school-aged children and adolescents from either historical and/or prospective growth data, it would be useful to reaffirm the operational difference between growth "references" and "standards." A reference describes the growth pattern of a defined population, whereas a standard defines a recommended pattern of growth that has been associated empirically with specified health outcomes and the minimization of long-term risks of disease.

Results and Discussion

Limitations of current growth references

The current NCHS/WHO growth reference for children and adolescents was based on the 1977 NCHS growth charts (19). Age-sex specific BMI percentiles (20) based on 1971–74 NHANESI data were endorsed for global use by WHO (21). The NCHS/WHO reference was developed from cross-sectional data collected from 4 separate samples of children and adolescents surveyed in the U.S. between 1963–1974. The NCHS/WHO reference may not describe optimal growth given the extent of its positive skewness in body weight, which is, unfortunately, a drawback shared by other more recent references such as the CDC 2000 reference and the IOTF cutoffs (22). The impact of the substantial upward skewness of these 3 references results in a substantial underestimate of obesity in school-aged children and adolescents (22–26).

In 1995, a WHO Expert Committee outlined several desirable features for the development of a new international growth standard (21): *1*) the sample should represent healthy children undergoing unconstrained, but not excessive growth, from several developing and developed countries; *2*) secular trends in growth should be small or absent in the sampled population; *3*) the sample size should be sufficient to reflect normal variance, and to estimate the more extreme percentiles of weight and height distributions; and *4*) cutoffs for under- and overweight should be derived in terms of specificity, sensitivity, and positive predictive values of functional and health-related outcomes.

Interpopulation variation in growth

The technical shortcomings of existing growth references are addressable, but the fundamental issue challenging the development of a single international growth standard is the legitimacy of combining subpopulations in light of possible genetic differences in growth potential. The universality of human growth was demonstrated for preschool-aged children reared under favorable nutritional and environmental conditions, regardless of genetic or ethnic background (27), and elaborated by Martorell and Habicht (28). The feasibility of developing a single international growth standard was challenged by Eveleth and Tanner (29) pointing to differences in achieved height and growth patterns across subpopulations of children and adolescents.

To expand on studies tabulated in *Worldwide Variation in Human Growth* by Eveleth and Tanner (29), Haas et al. (11) reviewed the literature since 1988 on interpopulation variation in achieved height. Growth data of nominally healthy, privileged children across the 5 major geographic regions of Africa, East Asia, South Asia, West Asia, and Europe, were compiled and compared with the NCHS/WHO reference. Multiracial immigrants moving to more advantaged environments were also included. Major findings from this latest review were as follows. African children and adolescents of upper socioeconomic status achieve similar heights to the NCHS/WHO reference medians, although studies are few. African American boys and girls achieved or exceeded the median values. Mean heights achieved by East Asian children and adolescents were below the NCHS/WHO median at all ages between 7 and 18 y, except for recent values from Beijing (30), and Taiwan (31). In these studies, heights were similar to the NCHS/WHO reference until puberty at which time mean heights fell to about the 25th percentile. Similarly, heights of boys and girls from South and West Asia tended to follow or were slightly below the NCHS/WHO until 11–13 y, at which time they fell to ~5 cm below the reference. The heights of children from central Europe tended to be 2–4 cm shorter than the NCHS/WHO median, whereas those from southern and northern countries tended to be similar. At puberty, mean heights of most European populations approached the reference median, except for adolescents from Northern Europe where heights were 4 to 7 cm higher than the reference at 18 y.

Although the above studies focused on nominally healthy, privileged children, secular trends in linear growth still may be occurring in some of the regions. Therefore, Haas et al. (11) compared the tallest children from various ethnic/geographical regions that presumably attained their genetic potential in linear growth. The mean heights of these boys and girls tracked along the median of the NCHS/WHO with a mean difference of ~5 cm between ages of 7 to 13 y. By the age of 15 y, the mean heights of Mexican American and Japanese adolescents fell to ~5 cm below and the Dutch means increased to ~5 to 7 cm above the reference. Mean heights of children living under privileged conditions worldwide did not vary by >4 cm from 7 y of age until the initiation of puberty. During adolescence mean heights in all populations, except those of European origin, were ~5–6 cm (~0.6 SD) below the NCHS/WHO reference median, and those from Northern Europe exceeded the reference median by 1.0 SD at 18 y of age. It remains to be determined whether these differences in adolescent linear growth for non-European populations represent full attainment or some unrealized gain in genetic potential. Whether the degree of geographic isolation and ancestral environmental exposures experienced by some subpopulations are sufficient to affect the genes that control linear growth is unknown. If subpopulation differences in height achieved under optimal environmental conditions persist, genetic differences in growth potential may be responsible.

Genetic determinants of growth

In general, growth parameters, including height and weight, are highly heritable traits (15). Also, determinants of human growth, such as the timing and tempo of puberty and other measures of skeletal and sexual maturation, are largely under genetic control. Weight, fat mass, and fat distribution are influenced to a larger extent by environmental factors, although genetic factors also are significant. Heritability estimates for growth parameters are lower in nonaffluent populations, probably due to more pronounced influence of specific nongenetic factors such as disease and nutrition in those populations. Limited data are available on cross-population effects of specific genes or gene variants on growth during childhood and adolescence. Genetic epidemiological studies are needed in different regions of the world to better explore population differences in gene frequencies and gene–environmental interactions. Although the fundamental genetic underpinnings of human growth are likely to be essentially the same worldwide, frequencies of allelic gene variants and gene by environmental interactions that influence growth and maturation might differ across populations. Their relative influence in different groups, however, remains unknown.

In the development of a single international growth standard, mean growth and normal variation in growth across populations must be represented. This should not pose an insurmountable problem because the largest variance in complex traits such as weight and height are usually contained within any sufficiently large sample of children from any given population.

There was a consensus among the working group that humans follow a similar pattern of growth across ethnic groups and geographic locations. When exposed to similar external conditioners of growth, subpopulations exhibit similar patterns of growth. This was demonstrated years ago for children <5 y of age (27) and was more recently confirmed by the WHO MGRS (32). Although the data for children older than 5 y of age are more limited, similar growth patterns across subpopulations were accepted as a general principle by this working group. Therefore, it was concluded that a single standard can describe universal human growth patterns. However, based on available data, it cannot be ruled out that some of the observed differences in linear growth across ethnic groups reflect true differences in genetic potential rather than the sole influence of environmental factors. Therefore, the sampling frame for the development of an international growth standard for children and adolescents would have to include multi-ethnic sampling strategies designed to capture the variation in human growth patterns.

Development of a new international growth standard

In the short term, a cross-sectional growth reference that approaches a standard for universal use could be constructed using carefully selected historical data sets that reflect realized growth potential and good health of school-aged children and adolescents (9). The reference population should be one that is stabilized in terms of secular increments in height and weight, and has not been subjected to discernible external constraints on growth (dietary deficiencies, infections, etc). But because historical datasets seldom have detailed subject descriptors, the health status of the cohort would be unqualified. Furthermore, the available datasets are not representative of the global population, and therefore, such an interim cross-sectional growth reference should be viewed as provisional.

In the long term, a mixed longitudinal growth standard reflective of the multiethnic populations across the regions of the world could be developed. Using prospective data to develop an international growth standard, a prescriptive approach is possible if careful consideration is given to selecting populations or subgroups that live in communities that support healthy lifestyles and thereby, presumably, optimal growth. Thus, communities sampled for the development of a growth "standard" would not be representative of nations' or regions' populations but would be uniquely defined on the basis of broadened criteria for health in a manner analogous to that of the new WHO growth standard for infants and preschool children (6). Criteria that specify healthy behaviors at the individual level would be applied to generate prescriptive-based data. Of great importance is that the samples selected should be free from obesity as well as constrained growth.

A mixed longitudinal design would produce the most useful growth data in the shortest period of time (13). The sampling frame for the development of a prescriptive growth standard would involve identification of a given number of countries that is broadly representative of the global community, drawing samples of children that are subject to inclusion and exclusion criteria to ensure unconstrained but not excessive growth. The sample size depends on the complexity of the growth curve; prior to puberty, the growth patterns for height and weight are relatively simple, in contrast to the more complex pattern of the pubertal growth spurt that would require a larger sample size.

Major environmental influences on growth of children and adolescents must be considered for the selection of individuals and populations in the development of an international growth standard (16,33). Inclusion criteria should encompass adequate nutrition, lack of significant endemic rates of infection, and socioeconomic status that does not constrain growth. Low birth weight, catch-up growth, breast-feeding and early adiposity rebound can impact growth and/or body composition into puberty. Exclusion criteria might include low birth weight due to identifiable pathologies and catch-up growth for individuals and high altitude and exposure to high levels of environmental pollution for populations. Populations with minimal evidence of secular trends in growth should be chosen. Positive secular trends have been documented in European, European-origin, and Asian populations where mean heights and weights across generations have been shown to be greater whereas sexual maturation and adolescent growth spurts have taken place at progressively younger ages. The mean secular increase in height in Europe and North America between 1880 and 1980 was more pronounced during adolescence because of the tempo effect (2–3 cm per decade) and less so during childhood (1–2 cm per decade) (29). In Japan between 1950 and 1980, the secular trend in height was almost entirely due to the increase in length of the legs. Age of menarche has been getting earlier during the last century by ~3–4 mo per decade in most European countries. The Japanese experienced a dramatic decline in the age of menarche between 1950 and 1975; at ~1.0 y per decade in the general population the age of menarche is as early or earlier than the majority of European populations. Negative secular trends also have been seen among populations in Africa, Papua New Guinea, and Latin America, largely attributable to socioeconomic and political deterioration; populations under such psychosocial stress should be excluded from the sampling frame.

Because biological maturation is closely related to growth, indicators of biological maturation, including sexual, skeletal, morphological, and/or dental maturity, must be included in the data collection for the development of a growth standard (14). The timing, sequence, and tempo of maturity indicators on growth must be considered. Skeletal maturation is usually monitored using standardized radiographs, and assessment of maturity is based on changes occurring from initial ossification to adult morphology of bones of the hand and wrist. Sexual maturation begins with early embryonic differentiation and ends with full maturity of the sexual organs and fertility. The assessment of sexual maturation is based on secondary sex characteristics, i.e., breast development, pubic hair, and menarche in girls, and genital development and pubic hair in boys. Ratings can be performed by clinical examination or self-examination using standardized drawings. The mean age at onset of the adolescent growth spurt occurs between 8.0 and 10.3 y, and the age of peak height velocity occurs 2 y later (10.8 to 12.2 y) in European and North American girls. Maturation events occur 2 y later in boys. Interindividual variation within populations is considerable. Indicators of sexual maturation, i.e., age at onset, age of peak height velocity, and skeletal maturity, are recommended indicators of the maturation process.

Direct methods for determining size and structure, including height, weight, skinfolds, and waist circumference, are well established and can be used to monitor linear growth, body mass, ponderosity, abdominal fat, and fat distribution (18). More complex body composition methods such as dual X-ray absorptiometry (DXA) and hydrometry would be desirable in view of mounting evidence of the relation of body fat to cardiovascular and diabetes risk in children and adolescents.

Measurement of physical activity and physical fitness as indicators of a healthy lifestyle should be incorporated in the development of international growth standards for children and adolescents (17). Physical activity plays an important role in the regulation of weight, fat mass, and the structural and functional integrity of bone and skeletal muscle, but probably not height or the maturation process. Physical fitness changes with age, growth, and maturation, independent of physical activity. Physical activity is assessed using questionnaires, interviews, diaries, direct or indirect (video) observation, film/video and motion sensors such as pedometers and accelerometers, heart rate monitoring, oxygen consumption, and doubly labeled water. Commonly used indicators of physical fitness are cardiorespiratory endurance (endurance shuttle run), function of the lower back (strength and flexibility), and many health-related fitness tests. Although data for children and adolescents are limited, they suggest a relation, although moderate, of physical activity and fitness to a favorable risk profile.

In conclusion, the working group agreed that the NCHS/WHO growth reference for school-aged children and adolescents, the CDC 2000 growth charts, and the IOTF cutoffs, all have shortcomings, and that a more appropriate growth standard for clinical and public health applications for these age groups should be developed. An international growth standard for school-aged children and adolescents could be constructed with careful consideration of the population and individual selection criteria, study design, sample size, measurements, and statistical modeling of primary growth and secondary ancillary data.

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