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Review Article

Practices of growth assessment in children: Is anthropometric measurement important?

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Assessing and monitoring growth is common practice in pediatric care, and health professionals accept routine growth monitoring in children as a standard component of community child health services throughout the world. In clinical level, by these activities one can detect and intervene while growth faltering happens. The internationally recommended way to assess malnutrition at population level is to take anthropometric measurements.[1] In developed countries, growth monitoring is an intrinsic part of 'well child' clinics. As growth is a proxy for child health, the child who grows well is generally healthy and illness in a child is usually associated with poor growth. Interpretation of child growth is based on anthropometric indicators established in a reference population with cut-off points to differentiate under- and overnutrition, short stature or tall stature, proportionate or disproportionate growth. Practices of growth monitoring consist of regularly measuring the weight and height of children, then plotting the information on a growth chart to make abnormal growth visible. When growth is abnormal, the health worker does something in concert with the family and as a result of these actions the child receives appropriate social or medical support, his or her nutrition improves, or a serious condition is diagnosed earlier.[2]

Reference curves of growth have been developed in many countries based on cross-sectional data.[3-5] The World Health Organization (WHO) has recommended an international reference based on growth standards developed within the United States during the 1970s.[6] In general, these growth references are used in Indonesian pediatric clinics although it is known that these references are based on United States children and it is not appropriate for use in other populations with different ethnic background without any adjustment. To this day, two separate charts have been developed in Indonesia more than 30 years ago but these were developed in a relatively limited geographical area. One chart dating from 1971 was developed for children between 6 to 18 years of age, and another one was developed in 1966 for children between 1 to 5 years of age; the reference children were from a village in West Java. These charts are widely used in primary health centers as reference charts, but since the 1977 NCHS charts were adopted by WHO as international reference in 1978, usage of the previous charts has been terminated and the CDC/WHO charts are now widely used by researchers.[7] A nationwide study to develop a national growth chart has been started in 2002, covering 7 different areas in

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Indonesia, i.e., 3 areas in Java and 1 area each in Sumatra, Kalimantan, Sulawesi, and Eastern Indonesia, respectively. With the existence of these growth charts, hopefully we can assess and monitor our children based on data obtained in our own population.[8]

The aim of this review is to focus on practices of growth assessment in pediatric care and to discuss anthropometric parameters used in evaluating and assessing the growth of children and its importance in clinical practice.

Anthropometric measurement

Growth charts are used universally in pediatric care for monitoring growth. Height and weight are the most widely used anthropometric measurements in assessing growth in children. Height is regarded as an indicator of overall health, while weight-for-age is the index mostly used in pediatric care. A study by de Onis *et al* in 2004 reported that out of 178 countries, 154 used growth charts; all used weight-for-age charts and only half used height-for-age charts.[9] Reference curves of growth have been developed in many countries based on cross-sectional data. Such curves are specific for each country, even though WHO has recommended an international reference based on US data during the 1970s.[10, 11]

Several other parameters can be used in monitoring growth of children. Body proportion will give a clue in the diagnostic work-up of skeletal dysplasia. Weight-for-height is another option in nutritional assessment, with some limitations. Body mass index (BMI) or quetelet index is an index most popular worldwide for assessing adiposity in children. To determine excess adiposity, both weight and height need to be measured; however, the cut-off point is still a subject of dispute since different approaches exist to set it.[12]

Other parameters used in growth monitoring practices are circumferences and skinfold thickness. Waist circumference, mid-upper arm circumference, and hip circumference are the circumferences most widely used in children. Skinfold thickness is usually measured at the biceps and triceps. Both parameters are also used as an index of adiposity. These measurements correlate directly to the amount of adipose tissue, but their accuracy remains to be discussed. Arm span and chest circumference are other measurements which should be considered in monitoring growth in children. Arm circumference is used in diagnosing skeletal displasias and chest circumference is used to evaluate nutritional status.

Distance standards

Height and weight

The primary tool for growth assessment is the growth chart. Growth charts exist based on height-for-age and weight-for-age, among others. Growth charts are intended to provide information on growth in children for clinical assessment. Measurement of height and weight is an important component of child health care and has been widely included in pediatric practice all over the world.[13] Measurements should be done with the highest quality possible, which requires proper measurement technique, training, equipments, and data recording. Height is measured using a stadiometer for children aged more than 2 years. Measurement is optimal when the child is relaxed, with legs fully extended and the head positioned in the Frankfurt plane, whereby the line connecting the outer cantha of the eyes and the external auditory meatus is perpendicular to the long axis of the trunk.[14] Measurement of supine length is used for children less than 2 years old. For measurement of supine length, we use a firm box built from inflexible board, against which the head lies, and a moveable footboard on which the feet are placed perpendicular to the plane determined by the supine length of the infant.[14]

The process of growth assessment involves single or multiple measurements of height and weight, and sometimes more specialized measurements, such as body proportion. The next step would be plotting the values to a suitable reference and interpreting it carefully. Finally, whenever necessary, we should find a solution for our interpretation.

In infancy, weight is more useful than length as its gain is up to 3 times greater, making it a sensitive marker of poor growth. Once infancy had passed, height is the most important measurement.[15] From the age of 1 year up to puberty almost all normal children growing along their 'track' on the centile curves. Before the age of 1 children can grow crossing the

centiles, upward if they grow fast and downward if they grow slowly; this is what we call 'catch-up' or 'catch-down', which are reflections of the statistical phenomenon 'regression to the mean'.[16] After infancy, centile crossing becomes less common, but once puberty begins and the adolescent growth spurt starts, centile crossing may occur again because of the tempo of puberty is different for every individual.

The modeling of height is divided into 3 phases, i.e., infancy, childhood, and puberty. In infancy, growth velocity starts high and falls rapidly, so that the growth curve flattens off with increasing age. After infancy, growth continues to fall slowly up to puberty and the growth curve is fairly linear. At puberty, the growth spurt occurs, growth velocity for height peaks, then falls to zero as adulthood approaches.[17]

The height and weight in the new Indonesian growth charts are described in nine centile curves. These are the 3rd, 5th, 10th, 25th, 50th, 75th, 95th, and 97th percentile curves, respectively.[8] The 50th centile is a median and identifies heights which split the population into 2 groups. The cut-off point for short stature is the 3rd centile, while that for tall stature is the 97th centile. In other countries, these may be expanded to include more centiles. For instance, the British growth chart uses the 0.4th centile as a cut-off point for further investigation; this is done to increase predictive value in screening for pathologic short stature.[18]

Weight for height

Obesity in children is increasing worldwide and becoming a public health concern. Therefore, routine health assessment should include adiposity.[19-22] Weight for age is often used as a single parameter in assessing overweight in children, but weight for age only, if not adjusted for height, could be misleading in assessing body weight. The same weight for the same age may give different information if height differences come into account. Weight for height is another way of expressing weight relative to height, but this weight for height charts are not age-specific. In the 2000 CDC growth chart, reference values for weight for height are only available for children with stature from 77 to <122 cm, so the use of this chart is limited to younger children.[7] The new Indonesian growth charts will provide weight for height references from birth to 18 years.[8]

Body mass index

It is good to see that children grow normally in stature, but a more important issue is whether they grow with ideal body weight relative to height. Therefore, to assess whether the child is growing normally, we should evaluate weight to height based on age group. Body mass index (BMI) is an index for assessing under- or overnutrition in adults and children. BMI is calculated as weight in kilograms divided by the square of height in meters. The BMI appears to be a widely accepted index for classifying adiposity in adults; cut-off points of 25 kg/m^2 and 30 kg/m^2 are recognized as the definition of overweight and obesity, respectively.[23] Since in children, BMI is age-dependent, there should be a curve of BMI based on age.

BMI reference charts have been published in several countries.[24-27] CDC has published BMI reference charts for children 2–20 years old containing its centiles. In the United States the 85th and 95th centiles of BMI, specific for age and sex, have been recommended as cut-off points to identify overweight and obesity.[4] The International Obesity Task Force (IOTF) proposed another definition of childhood obesity. Using data from 6 large national growth surveys, analyzed using the LMS method, centile curves were generated based on adult cut-off values (25 kg/m^2 for overweight and 30 kg/m^2 for obesity) at 18 years of age, then extrapolated down to younger ages. The resulting curve provided age- and sex-specific cut-off points from 2 through 18 years of age.[12] This new approach is mostly used in European countries.

Obesity in children is associated with chronic disease in adulthood, such as heart disease, hyperlipidemia, hyperinsulinemia, hypertension, and atherosclerosis.[28-32] Because of these risks in adult life, the tendency toward obesity should be monitored carefully. One of the parameters used widely for adiposity in children is BMI for age, even though it does not give a perfect correlation with adiposity. Despite this shortcoming, BMI for age is recommended as the appropriate indicator for assessing obesity in children.[33]

Arm span

Arm span is the longest distance from the tip of the third digit of the left hand to the tip of the third digit

of the right hand. It includes the width of the shoulders and the length of both arms and hands. For children older than 2 years of age, arm span is measured while the child is standing erect and his arms and hands are stretched out straight at 90 degree angles to the vertical axis. During infancy, arm span is equal to height. In the tallest children, arm span exceeds height by 9 cm up to puberty, but in shorter children, arm span never exceeds height until maturity. This means that the arm span to height ratio is smaller in shorter children.[34]

Other parameters

Body proportion

The usual method for measuring body proportion is to evaluate sitting height to standing height, subischial leg length to height, and to calculate the ratio of sitting height and leg length. Body proportion may provide important clues in the diagnostic work-up of children with skeletal dysplasias and exceptionally short or tall stature.[35-38]

Sitting height is measured using a sitting table, which comprises a rigid backboard and a horizontal headboard running perpendicular to the backboard, without crossplay. The child must be sitting with his feet on a footrest so that his full weight is on the buttocks. Arching of the back is avoided by gently applying upward traction to the mastoid processes in older children; stretching the back is achieved by asking the child to breathe deeply. The child's head is held in the Frankfurt plane; the lower borders of the orbits are in the same horizontal plane with the external auditory meatus. The subischial leg length is calculated by subtracting sitting height from the standing height.

There are significant racial differences in body proportions. Caucasians and Africans have relatively longer limbs compared to Asians.[35] Taller children have greater increments in leg length than do shorter children. Hence, the secular trend is mostly determined by leg length rather than rump length.[39,40]

Circumferences

Another form of anthropometric measurement is that of circumferences. These include waist circumference, mid-upper arm circumference, and hip circumference. Because of their simplicity and low cost, these simple anthropometric measurements remain the most commonly used tools for assessing body composition despite the existence of skin fold thickness.[6]

Waist circumference

BMI is used as indicator of overall adiposity and is recommended for identifying overweight and obesity in children and adolescents. Waist circumference has been advocated as an indicator of central adiposity because it is a good predictor of abdominal fat. Epidemiological studies have clearly shown that central adiposity is highly correlated with hypertension, coronary heart disease, type II diabetes, and increased mortality risk in adulthood. Maffeis[41] found that in girls, waist circumference is associated with risk factors such as insulin resistance and diastolic blood pressure.[41] Evaluation of waist circumference to height and waist-to-hip ratio has been studied to find the best predictors of cardiovascular risk factors in adolescents.[42]

Because of the postulated role of the visceral fat depot in health risks associated with obesity, waist circumference is now the preferred measurement in the context of population studies.[43,44] Waist circumference is measured using an elastic tape, midway between the lowest rib margin and the iliac crest. According to National Institute of Health guidelines, in adults the cut-off point for waist circumference to indicate a higher risk of obesity-related disorders is >102 in men and >88 cm in women. Because children are growing, waist circumference should be age-dependent. Currently no guideline exists for the classification of obesity-related health risks in children based on waist circumference, even though information on waist circumference percentiles are available in several countries.[14,45-49]

Mid-upper arm circumference

Mid-upper arm circumference (MUAC) is measured while the arms are relaxed and extended along the child's side. Mid-upper-arm circumference (MUAC) based on a single cut-off value for all children less than 5 years of age has been used for many years as an alternative nutritional status index for children. However, it has recently been questioned whether MUAC is independent of age and sex. After reviewing

the scientific evidence underlying the use and interpretation of MUAC, a WHO Expert Committee recommended a new MUAC for age reference for under-5-year-olds.[50]

Hip circumference

Hip circumference is measured on the upper thigh in a horizontal plane at the level of the gluteal fold. Large hip circumference seem to have a protective effect against cardiovascular morbidity and mortality in women, while waist circumference has the opposite effect.[51] A narrow waist with larger hips may protect against vascular disease.[52]

Skinfold thickness

A more direct measurement of body fat is skinfold thickness.[53] BMI as an indicator for obesity has some limitations; it has high specificity and lower but variable sensitivity. Because of this, only few adolescents can be classified correctly. Skinfold thickness will provide a better indicator for adiposity.[54] Skinfold thickness correlates well with obesity in children as defined by CDC criteria.[55]

Skinfold thickness can be measured at the biceps and triceps, the subscapular area, or the suprailiac area. Measuring at the biceps or triceps is preferred because of its relative ease and practicality. Skinfold thickness is usually measured on the upper arm midway between elbow and shoulder in the biceps and triceps region. In the subscapular area, it is measured over the lower tips of the scapula. In the abdominal region, it can be measured over the iliac crest. The measurement is taken by grasping the subcutaneous tissue between thumb and forefinger, then impinging the tissue using the caliper.[14,46] This procedure is relatively non-invasive and requires only simple technology. Although skinfold measurements is a better indicator for obesity than BMI, its accuracy is lower and it needs trained observers.[55]

Velocity standards

Growth velocity can be described as the increase or decrease in height or weight in a given period or as the rate of change in size over time. Velocity centile charts provide a more formal alternative for detailed follow-up, although it is not practical for general use. Each child requires at least 2 charts; this makes it more complicated for daily use. Growth faltering shows itself on a distance chart as a downward centile crossing. Children usually grow in a normal pattern through their channel. Centile crossing is normal in the first year of life; but after 1 year of age, usually there is no more centile crossing in height. At puberty centile crossing can be seen again. The timing of menarche in girls provides a proxy for the rate of maturation and the tempo of growth. It has been reported that the age of menarche has been falling sharply since the 19th century.[56] In Denmark[57] and Norway[58] it has been falling at a rate of up to 12 months per decade. However, nowadays this trend has halted and the age of menarche has remained constant at around 13 years.

Conditional standards

A conditional standard is a standard whereby the measurement is adjusted for a third factor in addition to age and sex.[59] The most popular is height conditional on parental height. Another conditional standard is height conditional on puberty. Adjusting height for parental height is important when investigating short stature. The child's target height is the mean of the parent's height (midparental height) adjusted for sex by subtracting 9 cm for girls or adding 9 cm for boys. This data should be plotted on the child's growth chart at the age of 18 along with its range.[8] The target height range indicates the child's probable growth pattern in centile terms. If the child's height centile is outside the range, this may indicate a growth disorder. However, such conditional standards cannot be calculated if one of the parents' height is unknown.[15]

Other factors to be taken into account

Ethnic minorities

National growth standards are usually based on national ethnic diversity.[60] However, in a very diverse

population, ethnic minorities could be poorly represented in the reference population. Producing minority-specific charts is impractical, as it requires an adequately large reference sample for the different possible combinations of ethnic minorities. The solution is to use a single national chart, with ethnic minority-specific adjustments based on an average centile band offset.[61]

Secular trend

Secular trends occur as a result of socio-economic improvement,[62] such as improvement in income and education.[63] Other factors which may affect secular change are family size[64] and urban versus rural residence.[65]

In England, a significant increase in body height is clearly seen when data of the 1978 and 1993 surveys are compared. This difference was suggested to be due to a secular change leading to earlier maturity and greater adult size.[66] Another example reported by Tanner is the increase in height in the Japanese between 1950 and 1980, which has occurred solely because of increase in leg length, without increase in sitting height, so that the trunk-leg proportion changed to resemble that of North Europeans.[67] It has long been known that children subjected to poverty and frequent episodes of morbidity are shorter on average than their rich, healthy contemporaries. In 1954, Thomson and Duncan proposed that leg length should be used as a more sensitive indicator of malnutrition in childhood than total stature.[67,68] It is clear that secular increases in stature are predominantly the results of an increase of the size of the lower part rather than upper part of the body.

The secular trend of height increase in Northern Europe is approximately 1 cm per decade,[69] while in Southern and Eastern Europe it is up to 3 cm per decade.[70] The tallest population in the world is the Dutch, whose young men and women averaged 184 cm and 170 cm in height, respectively.[71]

The most dramatic secular trends in the last two decades has occured in body weight, leading to worldwide concern of childhood obesity as a risk factor for later chronic diseases of affluence. The trend of obesity has been observed most clearly in the USA, but is also present in other countries. The consequence of the secular trend is the need for growth charts to be updated periodically.[72]

Prediction of final size

Height

Several approaches exist to predict adult height, the simplest of which is to assume that the child's current height centile will remain unchanged into adulthood. With this assumption, a child growing on the 50th centile is expected to become an adult on the 50th centile. The second one is by taking into account the child's bone age. The adult height can be predicted by calculating the percentage of maturation using the Bayley and Pinneau table[72] or Tanner-Whitehouse table.[73] The third approach predicts the child's adult height as the target height based on parental heights, as has been outlined previously. Such prediction of final height provides a useful guide on expected height for children from parents of average stature. However, it can be misleading when used to assess short children.

BMI

Adult BMI has been predicted by some investigators based on childhood BMI. Freedman et al found the association of childhood BMI with adult adiposity, but it is possible that the magnitude of this association depends on the relative fatness of children.[75] Correlation of adult BMI with child BMI at the age of adiposity rebound is only 0.3. A combination of BMI, skinfold thickness, and waist circumference may be better in predicting adult BMI, since the variance of BMI increases from 0% at birth to 40-50% at 10 years and 80% at 18 years of age.[76]

Conclusions

Anthropometric measurement is an important part of pediatrics and public health. Regular measurement should be done in order to detect growth faltering, especially during the first 5 years of life. Among the most important points in monitoring the growth of children are accuracy of measurements, plotting the results on a growth curve, and interpretation of the plotted growth. Hence, the availability of growth charts based on a country's own population is of utmost importance. In awareness of the worldwide increase in obesity, the BMI curve should be used regularly. Waist

circumference and skinfold thickness measurements are useful additions to BMI. In order to keep up with secular trends, height charts need to be updated regularly.

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