Pattern of growth in children with cerebral palsy

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ABSTRACT

Objective To provide a growth reference standard for children with quadriplegic cerebral palsy (QCP). Growth references specific to children with cerebral palsy would facilitate uniformity in clinical appraisal of their growth and nutritional status and would simplify comparative interpretation of growth data.

Design Weights and lengths were obtained according to standardized procedures. Measurements were taken at time of visit to an orthopedic clinic and from retrospective review of charts.

Subjects Three hundred sixty children with QCP. Growth data were based on 1,630 observations.

Analysis Growth curves representing the 10th, 50th, and 90th percentiles were estimated using a smoothing splines technique. Statistical bootstrapping was performed to confirm significant differences from the growth charts of the National Center for Health Statistics (NCHS).

Results Growth charts were constructed for boys and girls, aged 0 to 120 months, depicting length for age, weight for age, and weight for length. Average differences in length for age, weight for age, and weight for length between children with QCP and NCHS standards were –2.3 z, –2.4 z, –1.3 z for boys, and –2.1 z, –2.1 z, –1.1 z for girls. Children with QCP fell progressively behind in stature and weight. Compared with their NCHS counterparts, they were 5% shorter at 2 years of age and more than 10% shorter at 8 years of age.

Application Charts representing the pattern of growth in children with QCP should be accessible to parents and health care professionals to facilitate evaluation and monitoring of nutritional status. *J Am Diet Assoc. 1996; 96:680-685.*

Human growth corresponds to a predictable pattern. Growth deviation may be the first or only signal of a more serious underlying health problem that requires study. The earlier treatment is initiated, the better the chance of remediation and achievement of full growth potential.

Growth references permit the assessment of growth by defining the deviation from a population average. Using growth references to categorize nutritional status provides objective data for planning and program development. Trends in growth performance and nutritional status of one child or a population of children can be established. Reference data permit education of health care providers and families about the issue of growth as well as the evaluation of the impact of intervention strategies aimed at improving health.

Children with quadriplegia have alterations in muscle tone in all four limbs as well as torso involvement. They are unable to initiate movement, have limited physical activity, and experience frequent muscle contractures.

Table 1 presents a review of the literature relative to growth in children with cerebral palsy. Fourteen studies over a 40-year period are listed. The research conducted included a range of 5 to 179 subjects from 2 months to 21 years of age; the type of cerebral palsy was identified in only three studies. The findings of all reports were similar in that the children with cerebral palsy were described as shorter and lighter than the referenced standards. However, growth curves were not generated from any of these reports.

Most reference data on children's growth are based on the general pediatric population, so that application to children with cerebral palsy is inappropriate. Growth references specific to children with cerebral palsy would facilitate uniformity in clinical appraisal of growth and nutritional status and would simplify comparative interpretation of growth data. This article provides a reference growth standard for children with cerebral palsy.

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Table 1
Review of the literature relative to growth in children with cerebral palsy (CP)

Author, year	n	Age range	Type of CP	Findings
Leamy, 1953 (19)[a]	21	4-20 y	All	Children with CP are shorter than average children of similar age.
Sterling, 1960 (20)	100	6 mo-19 y	All	Children with CP are shorter and lighter than their normal siblings and than ranges on standard anthropometric charts.
Karle, 1961 (21)	12	2-10 y	Quadriplegia	Children with CP are shorter than average children of similar age.
Tobis, 1961 (22)	86	5-18 y	All	Height and weight of children with CP are significantly below accepted standards and below a matched age and ethnic clinic population.
Ruby, 1962 (23)	137	2-18 y	All	For height and weight, boys are 12-15 mo below the 16th percentile curve; girls are 18 mo below.
Eddy, 1965 (24)	5	13-16 y	All	Children with CP are shorter than average children of similar age.
Hammond, 1966 (25)	31	7-16 y	All	Children with CP are shorter and lighter compared with ranges on standard anthropometric charts.
Pryor, 1967 (26)	179	1-15 y	All	Standing height and all trunk diameters are in the normal range for the first 10 y, then show a definite slump, perhaps reflecting failure of the adolescent growth spurt.
Berg, 1973 (27)	23	7-20 y	All	Children with CP are short for their age and heavy for their height.
Gouge, 1975 (28)	118	2 mo-21 y	Handicapped	38% had height <3rd percentile; 32% had weight <3rd percentile.
Krick, 1984 (29)	24	8-34 mo	All	Children with CP are shorter and lighter compared with the National Center for Health Statistics standards.
Bandini, 1991 (30)	13	15-20 y	All	All children with CP were less than the 25th percentile height for age, and 92% had weight less than 25th percentile.
Stallings, 1993 (31)	142	2-18 y	Quadriplegia	This study describes growth retardation and documents reduction of fat stores and fat-free mass.
Stallings, 1993 (32)	154	2-18 y	Diplegia and hemiplegia	23% were stunted and 29% were underweight for age, while 8% to 14% were obese; there were no significant differences in growth between those with diplegia and those with hemiplegia.

[a]See reference list at end of article.

Table 2
Demographic characteristics of the study population

Characteristic	Girls		Boys	
	n	%	n	%
No. of children	175		185	
No. of data points	854		776	
Age (mo)				
Range	0.66-119.89		1.25-120.35	
Average	45.30		47.73	
Race				
Black	73	42	71	38
White	99	56	103	56
Other	3	2	11	6
Muscle tone				
Variable	294	34	308	40
Increased	523	61	434	56
Decreased	37	5	34	4
Method of feeding				
Tube fed	297	35	331	43
Oral	472	55	351	45
Both	85	10	94	12

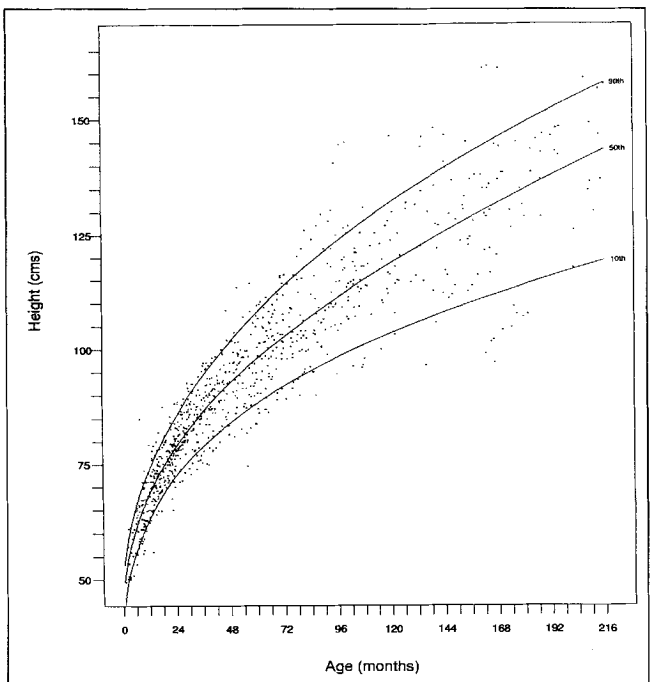

FIG 1. Scatter plot of raw data for length for age, girls aged 0 to 216 months.

METHODS

Subjects

Data were collected on 360 children with quadriplegic cerebral palsy (QCP). The entry criterion of a diagnosis of QCP was confirmed by review of physician notes in the medical record. Children were identified prospectively through an orthopedic clinic. Patients and families were asked if they would voluntarily participate in our data collection and had the option to refuse. Additionally, children were identified retrospectively through chart review using files of the nutrition department at Krieger Institute. Patients with known syndromes, renal disease, endocrinologic disorders, or cardiac disease were excluded from the study. Demographic data on the 360 children are shown in Table 2. The data included single observations for some children and multiple observations for others for both weight and length. Identification of route of feeding and classification of muscle tone were made at each interval of measurement.

Study Design

Weights and lengths were obtained according to standard protocol for all children (1). When possible, length was measured with the child recumbent on a stadiometer. If a child could not assume a flat position because of deformity, length was obtained segmentally by means of flexible tape. Alternative measures for determining height in children who are difficult to measure have not yet been adopted by Kennedy Krieger Institute.

The anthropometric measures were entered into the Centers for Disease Control and Prevention anthropometric software program (CASP, version 3.1, 1988, CDC, Atlanta, Ga). Deviation from the National Center for Health Statistics (NCHS) standards in standard deviation units (z scores) were obtained for the following parameters: weight for age, length for age, and weight for length.

Statistical Analysis

We estimated 10th, 50th, and 90th percentile curves for each group. The median curve, for example, keeps roughly half of the children's measurements above and below it. Figure 1 is an example of the raw data and fitted curves for girls aged 0 to 216 months. The QCP reference curves were estimated for the age interval 0 to 120 months because of the small number of children and data points represented at the upper age range of 121 to 216 months. Smoothing splines were used to estimate each curve (2). Smoothing splines are piecewise cubic polynomials tied together to have continuous first and second derivatives. A smoothing spline minimizes a criterion, which combines a measure of fidelity to the observations and a penalty for roughness. We estimated the quantile splines using methods analogous to those used for quantile linear regression (3).

To compare our growth curves with the NCHS standards, it was necessary to assess the uncertainty in our curves, which were based on relatively few persons (4). We used statistical bootstrapping for this purpose (5). In its most basic form, applied to a sample size of n, bootstrapping involves random resampling with replacement n values from the observed data, calculating the statistic of interest on the resampled data, then repeating this procedure many times to create a histogram that represents the variability in the quantity of interest. In this study, we resampled children and used all of the data available for each child to recalculate the percentile splines. This procedure was repeated 50 times. We found a statistically significant difference between the NCHS standard curves and our growth curves for children with QCP.

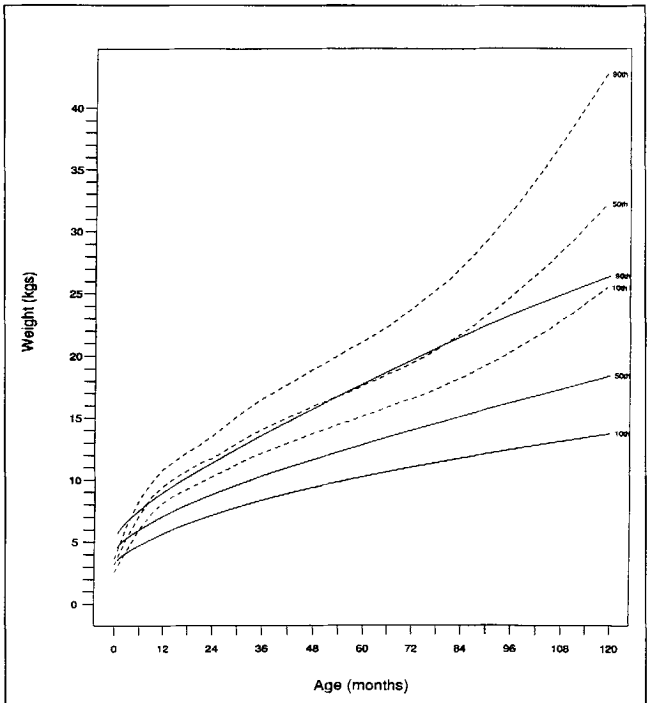

FIG 2. Weight for age for girls aged 0 to 120 months. The solid line represents girls with quadriplegic cerebral palsy and the dotted line represents the National Center for Health Statistics standard curve for 10th, 50th, and 90th percentiles.

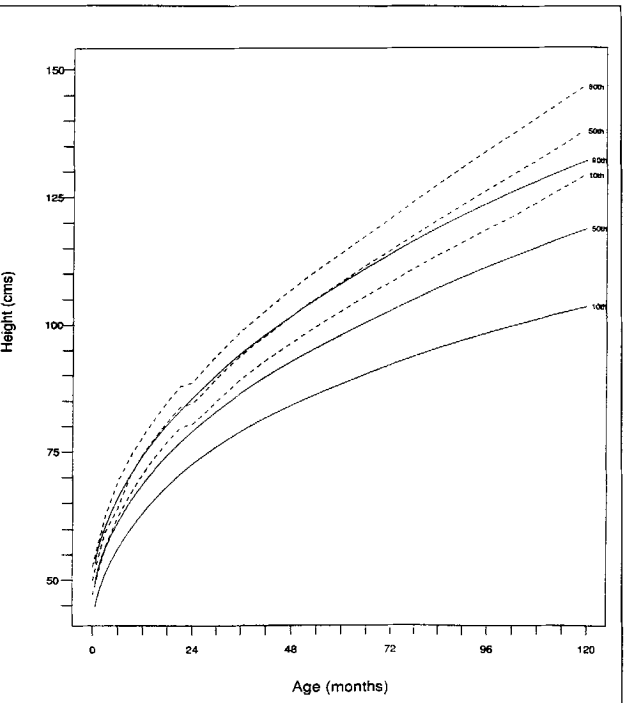

FIG 3. Length for age for girls aged 0 to 120 months. The solid line represents girls with quadriplegic cerebral palsy and the dotted line represents the National Center for Health Statistics standard curve for 10th, 50th, and 90th percentiles.

RESULTS

Comparison of Growth References with NCHS Standards

The growth references (Figures 2 through 7) presented describe girls and boys who are shorter and lighter for their age than their NCHS counterparts. Note that the 50th percentile of the cerebral palsy reference is below the 10th percentile of the NCHS standards for both genders for weight for age and length for age and is roughly equal to the 10th percentile for weight for length.

The average differences in length for age, weight for age, and weight for length between the children with QCP and the NCHS standard were –2.3 z, –2.4 z, –1.3 z for boys and –2.1 z, –2.1z, –1.1 z for girls, respectively. These findings characterize the boys as being further below the norm than the girls.

Growth Patterns

A comparison was made between QCP and NCHS curves using actual values for length for age and weight for age at 2-year intervals for each of the percentiles depicted. Analysis indicated more variability in the growth of children with QCP compared with NCHS standards. This variability was greater at the 10th percentile than at the 90th.

As the children got older, the differences between the study population and the standards increased. Additionally, the rate of growth in the study population was slower compared with the standard reference. In the normal population, somatic growth rate is stable between the ages of 1 and 10 years. The children with QCP were 5% shorter at 2 years of age and more than 10% shorter at 8 years of age.

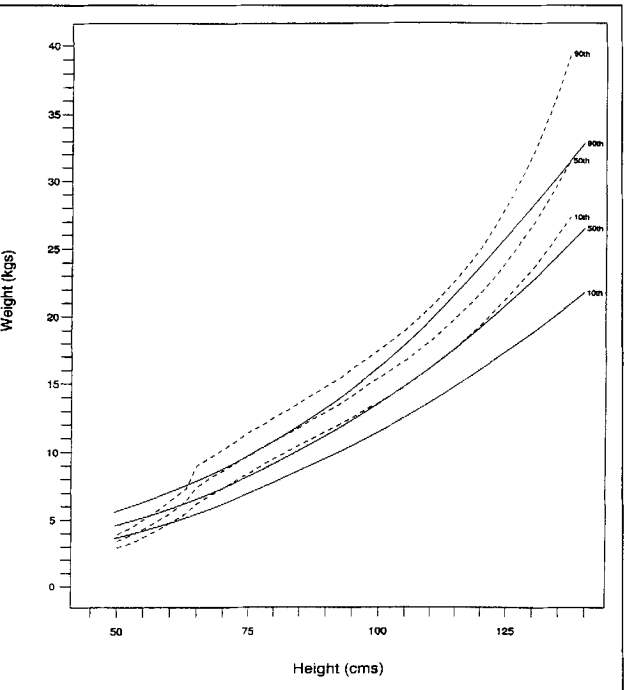

FIG 4. Weight for length for girls aged 0 to 120 months. The solid line represents girls with quadriplegic cerebral palsy and the dotted line represents the National Center for Health Statistics standard curve for 10th, 50th, and 90th percentiles.

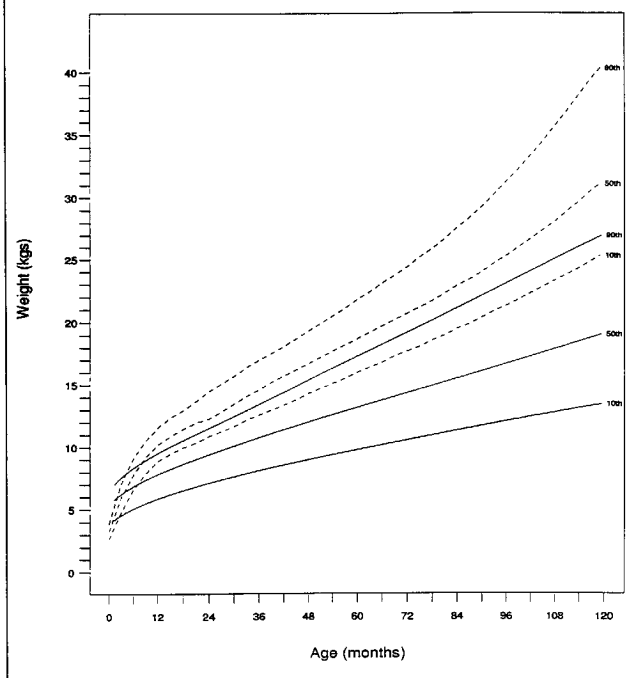

FIG 5. Weight for age for boys aged 0 to 120 months. The solid line represents boys with quadriplegic cerebral palsy and the dotted line represents the National Center for Health Statistics standard curve for 10th, 50th, and 90th percentiles.

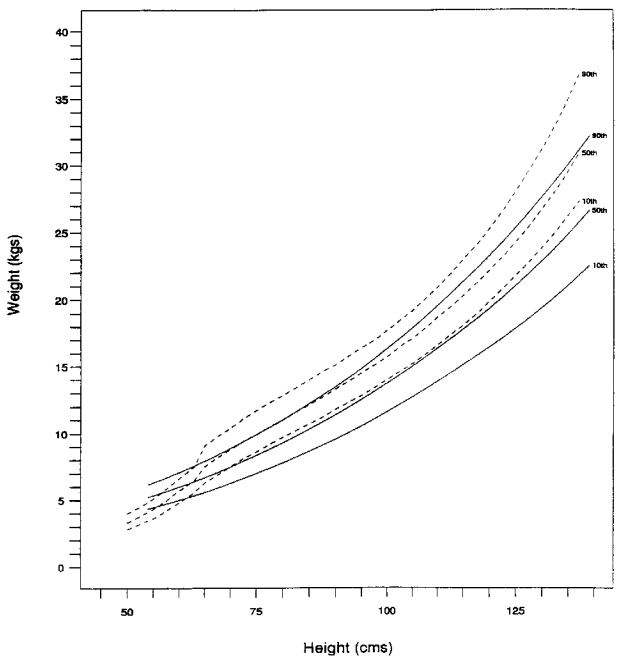

FIG 7. Weight for length for boys aged 0 to 120 months. The solid line represents boys with quadriplegic cerebral palsy and the dotted line represents the National Center for Health Statistics standard curve for 10th, 50th, and 90th percentiles.

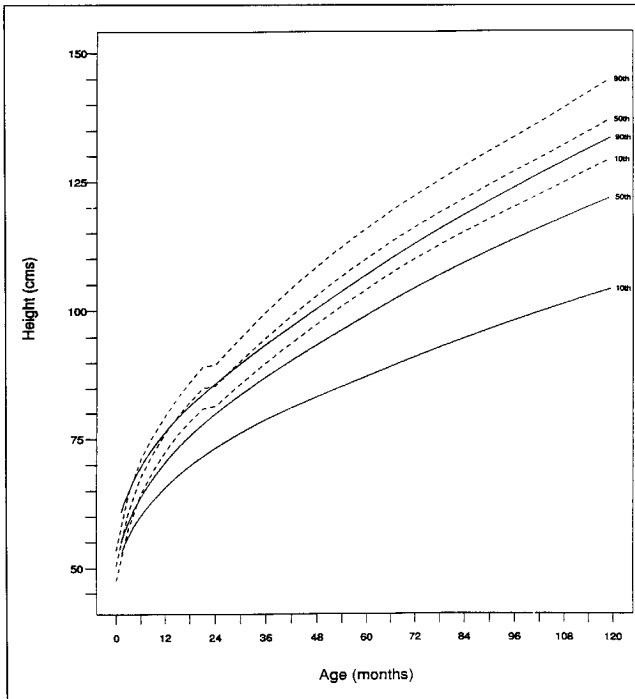

FIG 6. Length for age for boys aged 0 to 120 months. The solid line represents boys with quadriplegic cerebral palsy and the dotted line represents the National Center for Health Statistics standard curve for 10th, 50th, and 90th percentiles.

DISCUSSION

Quadriplegia is the most common pattern of cerebral palsy; it is found in 27% of the total population with cerebral palsy (6). The prevalence of cerebral palsy among children entering school is 2 per 1,000 live births (7). The growth reference standard presented here is confined to this population.

Seizure disorder is an associated deficit seen in many children with cerebral palsy. Although this study did not specifically review the medication use of the subjects, a recent article by Kurowski and colleagues (8) found that neither the number of years taking anticonvulsant medication (carbamazepine or valproic acid) nor the total amount of medication taken had a significant effect on weight, and linear growth was normal. These findings suggest that commonly used anticonvulsant medications are not a confounding variable in growth.

There are many possible reasons why children with quadriplegia are shorter than their NCHS counterparts. Shapiro et al (9) noted that nutritional factors alone were not responsible for the linear growth retardation seen in a population of severely impaired children. A recent work by Stevenson et al (10) evaluated well-nourished children of normal height and with hemiplegia. After many anthropometric measurements were completed, significantly smaller differences of breadth, circumference, and length were noted on the affected side compared with the nonaffected side. The authors suggest that nonnutritional factors and disease severity have a notable influence on the growth of children with cerebral palsy. Children with quadriplegia are nonambulatory and non–weight-bearing; thus, normal stress on their bones is reduced. Bone contains growth factors such as insulin-like growth factors, transforming growth factor, platelet-derived growth factor, basic and acidic fibroblast growth factor, and bone morphoge-

netic proteins (11,12). The production of these growth factors is regulated by both systemic hormones and local mechanical stress (13). Bone growth studies suggest that immobilization decreases bone formation and longitudinal bone growth and increases bone resorption, which suppresses certain growth-stimulating hormones (14,15). The majority of our subjects were categorized as having increased muscle tone. Strodel (16), writing in the dental literature, suggests that muscle spasticity retards bone growth. The report notes that variations in the tone of the head and neck muscles may cause malocclusion and arch deformity. Coniglio et al (17) suggest that dysregulation of growth hormone secretion may play a role in the growth failure noted in this population. Although it is difficult to identify primary cause, a combination of non-nutritional factors, including inactivity, circulatory changes in the bone, changes in piezoelectrical forces on bone, and changes in neural stimulation of bone and parietal lobe defects associated with sensory deficits, are discussed in the literature (18).

There are also many possible reasons why children with quadriplegia are lighter than their NCHS counterparts. These include oral-motor dysfunction, lengthy mealtimes, dysphagia, gastroesophageal reflux, and parental/caretaker desire to maintain their child at a manageable weight.

To refine the description of growth in children with QCP, studies are needed that include such variables as prenatal and perinatal factors, familial growth patterns, endocrine status, role of nutrient intake, number and type of surgical procedures, overall health status, body composition, use of medication, socioeconomic status, and place of residence. About 50% of the population we described were partially or wholly tube fed to meet nutrition needs (Table 2). Further data analysis could compare those who are tube fed with those who are not.

Compared with previously published reports on growth in children with cerebral palsy, this study differs in several important aspects. This review involved a larger population and was specific in regard to gender and to those with quadriplegia. In addition, growth references were developed for the growth indexes of weight for age, length for age, and weight for length.

APPLICATIONS

Population-specific data provide appropriate comparisons for growth velocity and a more realistic picture of weight for age and length for age for children with QCP. Arm anthropometry describes body composition in relation to weight and should be used to provide additional data for assessing growth. Currently, ideal body weight for this population is estimated at the 10th percentile weight for height on the NCHS charts, allowing for adequate body stores of fat and muscle as determined by arm anthropometry and laboratory indexes. Initially, it is proposed that the charts presented in this article be used in conjunction with the NCHS growth charts and that the 50th percentile weight for height according to the QCP reference be the goal. Given the important findings of this investigation, use of population-specific references to facilitate evaluation and monitoring is recommended to all clinicians.

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