Growth patterns in a population of children and adolescents with cerebral palsy

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This study examined growth of children and adolescents with cerebral palsy (CP) who received services from the California Department of Developmental Services from 1987 to 2002. In all, 141 961 measurements of height and weight were taken from 24 920 patients with CP (14 103 males, 10 817 females). Centiles of weight and height were determined by age, sex, and five levels of functional ability ranging from fully ambulatory to unable to walk, crawl, or feed self, and fed via gastrostomy tube. Resulting charts of height and weight centiles were compared with Centers for Disease Control and Prevention weight and height charts for the general population of the US. Centiles of height and weight of patients with CP were close to those of the general population for the highest functioning groups with CP, but lagged substantially for other groups. Presence of a feeding tube was associated with greater height and weight in the lowest functioning groups, with centiles for weight being 2 to 5kg higher for those with gastrostomy tubes. The charts may assist in early identification of nutritional or metabolic difficulties beyond what might be expected for patients with similar functional disabilities.

See end of paper for list of abbreviations.

Patterns of human growth are predictable.[1] As significant deviations from predicted patterns may indicate serious underlying health problems, early identification is important for timely treatment. Thus, plotting a child's weight and height on charts that permit direct comparison with age and sex-specific centiles in the general population[1] has become standard practice for pediatricians.

Studies have documented that growth patterns for patients with cerebral palsy (CP) are different from those in the general population.[2–13] Patients with CP have below average weight,[2] linear growth,[2,13] muscle mass,[2] and fat stores[2] compared with their peers in the general population. Bone mass density is also reduced, especially among patients who are non-ambulatory.[3]

Feeding difficulties and resulting nutritional problems are partly responsible for these deficits in growth.[2,5–9] Stepwise increases in level of feeding difficulty have been shown to correspond with successive decreases in nutritional status as measured by weight, stores of body fat, and arm muscle mass.[2] However, this stepwise relationship did not hold for patients with the most severe feeding difficulties who received nutrition primarily via a feeding tube: these patients weighed more, and had more muscle mass and fat stores than peers with a similar disability who took all food orally.[2]

However, non-nutritional factors also contribute to the deficits in growth in patients with CP.[7,8,11] For instance, patients with hemiplegic CP who had statures and triceps skin-fold measurements within population norms had significantly smaller length and girth measurements of limbs on their affected side than their unaffected side.[11] Other studies similarly found involved limbs to have delayed skeletal maturation[14] and reduced bone density[15] compared with uninvolved limbs. Thus, muscular atrophy in affected limbs appears to impede growth independently of poor nutritional intake. Endocrine function may also be impaired in patients with brain injuries involving the pituitary gland, and the question of whether growth hormone treatment may be beneficial to some patients with CP has been considered.[16]

Although plotting growth of children with CP on standard Centers for Disease Control and Prevention (CDC) charts[1] often reveals significant departures from population norms, it is often unclear whether the departure is typical for children with CP. That is, although a child with quadriplegic CP may fall below the 10th centile on the CDC charts, that patient may be at or above the 50th centile for children with CP and comparable neuromotor dysfunction. Growth charts for children with CP stratified by level of motor or feeding dysfunction would be valuable for the assessment of a child's nutritional status. Such charts would also provide prognostic information on future weight or height. This information could help families and caregivers in determining what resources they may need to help their child with transfers (e.g. from bed to wheelchair), activities of daily living, or how often they may need to fit new appliances such as ankle–foot orthotics or a wheelchair.

We present growth charts for patients with CP based on measurements from a large population of patients who have received services from the State of California Department of Developmental Services (DDS). A novel feature is that growth curves are stratified by severity of disability, as measured by feeding ability and motor function. This study also extends to age 20 the results of Krick et al.,[4] who provided growth curves for children with severe quadriplegic CP to age 10 years.

Method

We identified patients with CP aged 2 to 20 years who received services from the State of California DDS between January 1, 1987, and December 31, 2002. The DDS provides early intervention, occupational and physical therapy, equipment, case management, and respite and social services for all state residents with CP who have a substantial disability.[17] CP is defined for this purpose as 'a non-progressive lesion or disorder in the brain occurring during intrauterine life or the perinatal period and characterized by paralysis, spasticity, or abnormal control of movement or posture which is manifest prior to 2 to 3 years of age'[1] and 'other significant motor dysfunction appearing prior to age 18'.[2,18] We excluded patients with diagnoses suggesting CP of postnatal origin (traumatic brain injury, near drowning, motor vehicle accident, brain tumor, other acquired injuries) as well as patients with significant concomitant diagnoses (autism, Down syndrome, degenerative disorders).

Individuals receiving services from the DDS are evaluated annually using the comprehensive Client Development Evaluation Report (CDER). This report contains more than 200 medical, functional, behavioral, and cognitive items, and is completed by physicians, psychiatrists, and social workers as required. Physicians make the assessments of medical diagnoses, including the assessment of CP, while functional status, weight, and height are assessed by physicians or other professionals most familiar with that aspect of the patient's development. In some cases, evaluators may record weight or height as reported by a parent or other caregiver. The interrater reliability of the motor functioning variables in the CDER has been shown to exceed 0.85.[19] Discrepancies between weights recorded on the CDER and those found in an individual's actual medical records were found in 9% of a random sample of CDERs, but these were deemed small enough to be considered immaterial.[20] Possible discrepancies in height were not addressed.

Patients with more severe CP tend to weigh less and be of smaller stature generally than those with less severe disability.[2,3,5,12] We, therefore, formed groups of children with CP stratified by gross motor skills (walking, crawling, and standing) and feeding ability. Criteria for inclusion in each group were: (a) group 1: walks well alone for at least 6 metres and balances well; (b) group 2: walks with support or unsteadily alone for at least 3 metres, but does not walk well alone for at least 6 metres or balance well; (c) group 3: crawls, creeps, or scoots; but does not walk; (d) group 4: does not walk; does not crawl, creep, or scoot; does not feed self; is not fed by gastrostomy tube; and (e) group 5: does not walk; does not crawl, creep, or scoot; does not feed self; is fed by gastrostomy tube.

Each group was also stratified by sex. Note that the categories are not exhaustive. A patient who otherwise meets the criteria for group 4 but has some self-feeding ability would not fit any category exactly. Our purpose in defining groups 4 and 5 as we have was to allow comparison of the group who are fed via gastrostomy (group 5) with a group with severe disability who were not (group 4). Patients who feed themselves but otherwise meet the criteria for group 4 would presumably have growth trajectories somewhere between those of groups 3 and 4.

For each functional group and sex, centiles of weight, height, and body mass index (BMI) were determined using SAS statistical analysis software[21] and plotted against age. The curves were smoothed using the 'super smoother' function of S-PLUS.[22] The resulting charts provide curves for the 90th, 50th, and 10th centiles of weight for age among the five functional groups of patients with CP.

For comparison, the 90th, 50th, and 10th centiles in the US general population (females or males) were also plotted on each graph.[1] For weight, the 3rd centile for the general population was also included.

ETHICAL APPROVAL

This study has received ethical approval from the Institutional Review Board of the Office of Research Affairs, University of California at Riverside.

Results

We identified 24 920 patients with CP (14 103 males, 10 817 females) from whom 141 961 measurements of height and weight were obtained. BMI was calculated as weight in kilograms divided by the square of height in metres. The distribution of numbers of measurements across groups and ages is given in Table I. Because functional abilities often changed as

Table I: Number of measurements (participants[a]) in each group by age and sex

	Age, y	*Group*				
		1	*2*	*3*	*4*	*5*
Female	2–5	2151 (1254)	3127 (1904)	2561 (1493)	2232 (1191)	705 (386)
	5–10	5267 (1971)	5704 (2287)	3501 (1368)	2734 (1032)	1144 (435)
	10–15	5307 (1881)	4487 (1686)	2860 (1013)	2305 (790)	981 (348)
	15–20	5823 (1917)	4593 (1564)	2811 (893)	2345 (737)	922 (313)
Male	2–5	3185 (1864)	4316 (2610)	3668 (2162)	2864 (1512)	962 (515)
	5–10	8049 (2908)	7299 (2833)	4883 (1860)	3390 (1281)	1471 (559)
	10–15	7293 (2590)	5484 (1999)	4024 (1402)	2457 (881)	1118 (399)
	15–20	7759 (2495)	5002 (1720)	3863 (1252)	2325 (768)	989 (339)

Groups: 1, Walks well alone for at least 6 metres, balances well; 2, Walks with support or unsteadily alone for at least 3 metres, does not walk well alone or balance well; 3, Does not walk, but crawls, creeps, or scoots or has better crawling and standing ability; 4, Does not walk, crawl, or feed self, no feeding tube; 5, Does not walk, crawl, or feed self, feeding tube. [a]Note that participants may contribute to more than one cell as they grow older and their functional abilities change. Thus, row and column totals for each sex exceed study population totals of 10 817 females and 14 103 males.

patients got older, many participants in the study contributed measurements to more than one group during the study period.

For illustration, weight charts are provided here for females in the highest functioning group 1 (Fig. 1) and lowest functioning group 5 (Fig. 2). All other charts are available at www.LifeExpectancy.org/Articles/GrowthCharts.shtml.

At most ages, centiles of weight for females in group 1 (able to walk well alone for at least 6 metres, balance well) are only slightly below those of the general population (Fig. 1), and by age 20 the 90th centile was actually slightly higher for patients with CP. Weights for the highest functioning males with CP were also close to those of the general population at young ages, but at older ages the weights of males with CP fell consistently below weights in the general population; by age 20 the 90th centile of weight for males in group 1 was 3% below, and the 10th centile 23% below the corresponding figures for the general population.

Weight centiles for males and females in group 2, who ambulate unsteadily alone or with supportive devices, were clearly less than in the highest functioning groups. The differences generally widen as age increases.

The trend of lower weight continues with the still lower functioning groups 3 and 4. Among patients in group 4, most have weights below the 10th centile of the general population, and medians are more than 20% below those of the general population as early as age 2 years. By age 20 years, the female median for group 4 is only 59% of the general population median, and the male median only 51%. This increasing gap with age is attributable to the differential growth pattern of the groups with functional abilities that have the most impairment. These groups tend to show a straight-line increase in weight, rather than the logistic (S-shaped) curve observed in the general population. That is, the patients with severe CP tend not to display the 'growth spurt' of their peers without CP.

The patients in group 5 have functional abilities similar to those in group 4 but have feeding tubes. The patterns of weight gain in these two groups are similar, but centiles of weight for those with feeding tubes are 2 to 5kg higher than those fed orally. The magnitude of the increase in median weight (expressed as a percentage of median weight in group 4) at various ages and by sex are given in Table II. The differences are small at age 2 (5% for males, 10% for females), peak at approximately age 10 (30% for males, 19% for females), and narrow again by age 18 years (4% for both males and females). Comparisons for height, BMI, or for centiles other than median can be made by reading figures directly from the growth curves. In almost every case, centiles for those fed orally (group 4) are lower than for those with feeding tubes (group 5).

Patterns for height roughly parallel those for weight, though in general deviations from heights in the general population are not as large. Those in group 5, who had severe disabilities and were fed via a gastrostomy tube, also had somewhat greater heights than those with severe CP who were fed orally, suggesting that nutritional factors play a significant role in linear growth of patients with severe CP. Heights of females

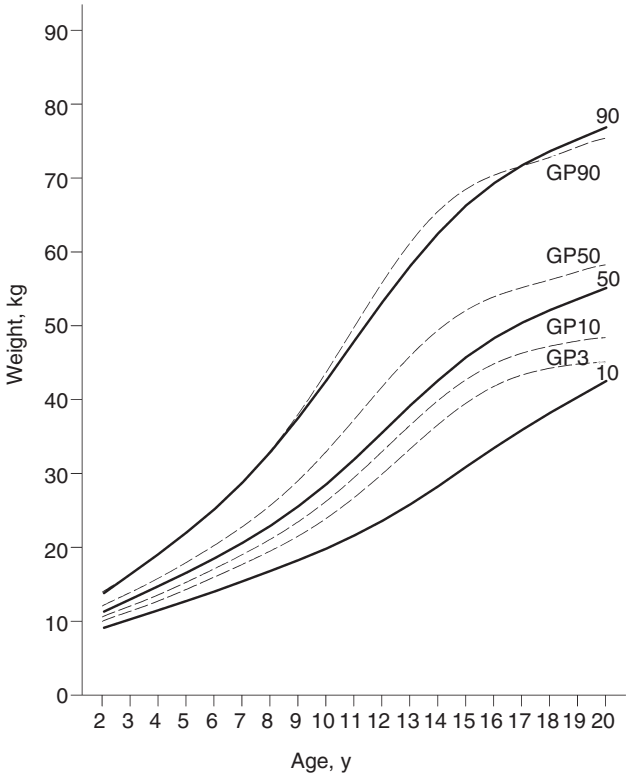

Figure 1: *Weight for age centiles: females 2–20y. Cerebral Palsy Group 1 (solid); GP, General Population (dash). Group 1 walks well alone for at least 6 metres, balances well.*

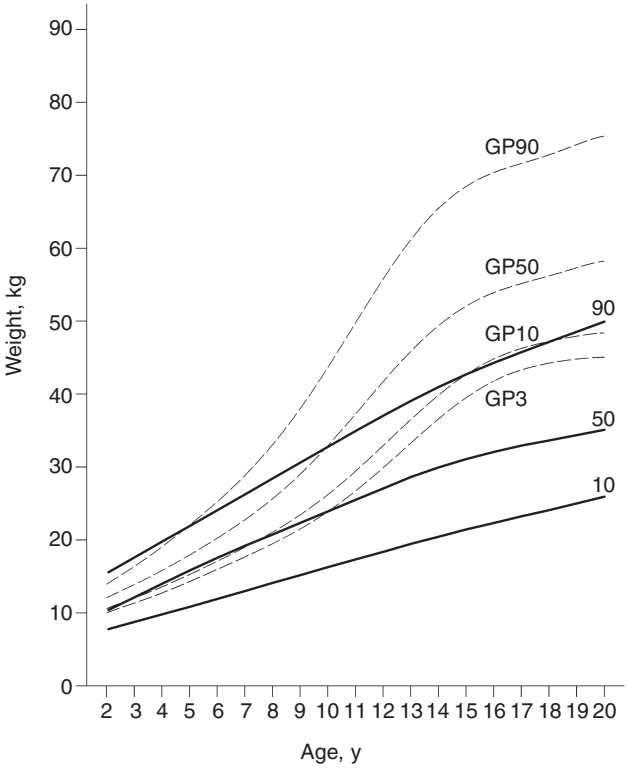

Figure 2: *Weight for age centiles: females 2–20y. Cerebral Palsy Group 5 (solid); GP, General Population (dash). Group 5 does not walk, crawl, creep, scoot. Does not feed self; feeding tube.*

and males with only minimal disability (group 1) were close to those of the general population, and the curves showed characteristic earlier growth for females, with medians at age 12 being nearly identical for males and females in this group (138 and 139cm), but with heights of males overtaking the females' by age 20 (medians 157cm for females, 168cm for males).

Figure 3 shows a direct comparison of centiles of weight of: (1) males with quadriplegic CP developed by Krick et al.;[4] (2) our group 4 (who did not walk, crawl, or feed themselves); and (3) patients in the California database identified only as having quadriplegic CP. Centiles of weight for Krick's group and our group 4 are very similar, while our patients with quadriplegic CP had substantially higher centiles.

Centiles for BMI of patients with CP were consistently lower than corresponding centiles in the general population, again with larger differences for greater levels of disability. However, group 5 (who were fed via feeding tube) had higher centiles of BMI than group 4 (who had severe CP but took all nutrition orally).

Table II: Percentage increase in median weights attributable to use of feeding tube[a]

Age	*Males, %*	*Females, %*
2	7	5
5	19	16
10	29	30
15	26	17
20	10	4

[a]Figures are calculated as ([median in group 5]–[median in group 4]) ÷ (median in group 4) × 100%.

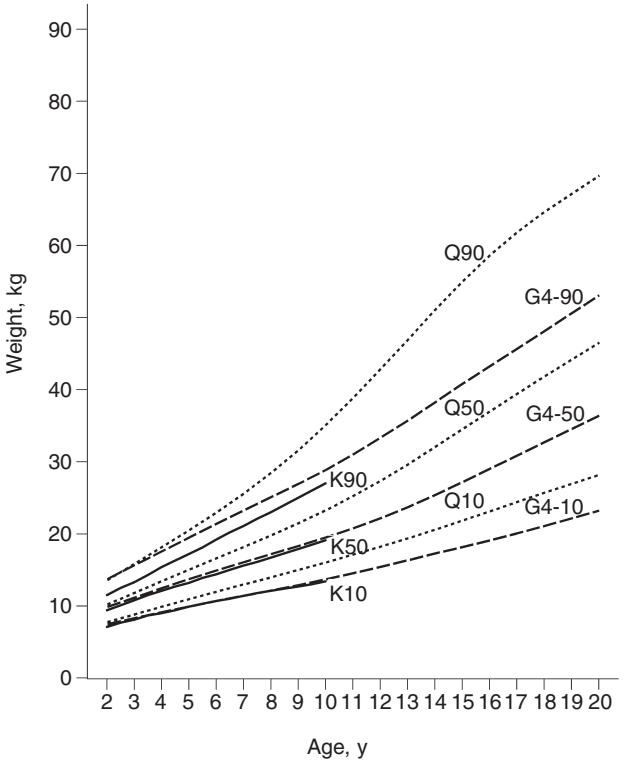

Figure 3: *Weight for age centiles: males, comparison with Krick et al.,[4] 2–20y. G4, Cerebral Palsy Group 4; Q, Quadriplegic; K, Krick. Group 4: does not walk, crawl, creep, or scoot; does not feed self; no feeding tube.*

Discussion

Krick et al.[4] made a significant contribution to the question of CP-specific growth patterns in producing charts based on 1630 measurements of height and weight of 360 patients (185 males, 175 females) with quadriplegic CP. The authors plotted growth curves showing 10th, 50th, and 90th centiles and found that in this group of patients average deviations from the National Center for Health Statistics standards[23] for weight by age were –2.4 standard deviations (SD) for males and –2.1 SD for females. They found very similar differences in length for age.

The growth charts presented here show that patients with CP who have only minimal motor dysfunction can be expected to achieve weights and heights close to those of the sex- and age-matched general populations. For patients with CP and significant motor dysfunction or feeding difficulties, departures from general population weights and heights are significant, making standard growth curves of little value in monitoring their growth.

The difference in weight between high functioning adolescent males with CP and those in the general population is larger than the corresponding difference for females (Figs. 1 and 2). This may be partly attributable to levels of physical activity or attitudes about weight among adolescents. One study has shown that peer and family issues may exert different pressures in these areas for adolescents with CP, with these young adults tending to have limited out-of-school contacts with friends, negligible participation with organized social activities, and a primary orientation toward sedentary activities.[24] More research in these areas is needed to understand fully the different patterns for adolescent males and females with mild CP and those in the general populations.

Centiles of weight for our California population of patients with quadriplegic CP were substantially higher than those of Krick et al.[4] (Fig. 3). This is likely to be due to differences in levels of functional abilities in the two groups. Krick et al.[4] described their quadriplegic population as being 'unable to initiate movement' and as having 'limited physical activity' and roughly 40% were tube fed. In contrast, the definition of quadriplegia used by the DDS includes any person with four-limb involvement, regardless of the level of dysfunction, and many in the California population with quadriplegic CP had significant fine and gross motor functioning, some being fully ambulatory. Though we do not know the precise level of motor functioning of the Krick population, their weight centiles are close to those of our group 4 (who do not walk, crawl, or feed themselves, and are fed orally) for males and females (Fig. 3).

Our finding that weights and heights for those fed by gastrostomy tube were greater than those of patients with severe CP fed orally (Table II) is consistent with findings of Fung et al.[2] These researchers reported that patients with CP at Level V (severe disability) of the Gross Motor Function Classification Scale[25] who were fed via gastrostomy tube weighed more than those fed orally. Though some patients are clearly in need of a feeding tube to ensure adequate nutrition (e.g. in cases of obvious failure to thrive, unreasonably long times for oral

feeding, or severe gastroesophageal reflux), other patients may have more subtle feeding problems. It is possible that some patients presently not fed via gastrostomy tube would benefit from the procedure. Further investigation of the clinical effects of feeding tube placement in children who are thought to have only moderate feeding difficulties is warranted.

The weight and height curves presented here for patients with CP provide values (centiles) comparable with a population norm based on a large California population from 1987 to 2002. While representative of a large population of patients with CP, and stratified according to level of disability, the charts do not necessarily represent ideals for height or weight for the given groups. As recent work has shown, interventions in oral feeding can result in weight gain, and future interventions may result in improved height as well.[2] What an ideal weight or height might be for a child or young adult with CP is a complex question in any event, especially for those with severe CP.

Our study has at least two limitations. First, patients with milder motor dysfunction may have been preferentially lost to follow-up. That is, although DDS continues to offer services to children with CP and motor disability as they grow older, those with only very mild motor dysfunction may voluntarily decline further services due to perceived lack of need. If this has occurred, the resulting growth curves for the highest functioning groups may underestimate centiles of height and weight to some degree. Growth curves for those with more severe motor dysfunction (groups 2–5) would not be significantly impacted by this potential bias.

Second, in contrast to the weight variable, height as recorded on the DDS CDER has not been validated. Usual warnings about the difficulty in measuring height in children with significant motor impairment apply here, especially for groups 3, 4, and 5. The height curves presented for these groups should be viewed with some caution.

Strengths of the study include the large numbers of patients and measurements on which the curves are based, and the stratification of growth trajectories according to levels of motor and feeding dysfunction. Plotting weight and height of children with CP on the charts provided (www.LifeExpectancy.org/Articles/GrowthCharts.shtlml) may assist caregivers in the early identification of nutritional or metabolic difficulties beyond what might be expected for patients with similar functional disabilities.

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List of abbreviations

BMI	Body mass index
CDC	Centers for Disease Control and Prevention
CDER	Client Development Evaluation Report
DDS	Department of Developmental Services