

Validation of US cerebral palsy growth charts using a UK cohort

CHARLOTTE M WRIGHT¹  | LUCY REYNOLDS² | EMILY INGRAM¹ | TIM J COLE³ | JORDAN BROOKS⁴

1 Department of Child Health, MVLS College, University of Glasgow, Glasgow; **2** Specialist Children's Services, NHS Greater Glasgow and Clyde, Glasgow; **3** Department of Life Course Epidemiology and Biostatistics, Great Ormond Street Institute of Child Health, University College, London, UK. **4** Life Expectancy Project, San Francisco, California, USA.

Correspondence to Charlotte M Wright at Royal Hospital for Children, CO/2 Office Block, Govan, Glasgow G51 4TF, UK. E-mail: charlotte.wright@glasgow.ac.uk

PUBLICATION DATA

Accepted for publication 19th April 2017.

Published online

ABBREVIATIONS

BMI	Body mass index
LMS	Lambda-mu-sigma
UK-WHO	Combined World Health Organization and UK 1990 growth reference

AIM Growth charts for cerebral palsy (CP) have been constructed using data for 24 920 Californian patients, covering ages 2 to 20 years, with separate charts for the five severity levels of the Gross Motor Function Classification System (GMFCS). Our aim was to test how the data for British children with CP fit these charts, compared with conventional local charts.

METHOD US CP growth reference was reanalysed using the lambda-mu-sigma (LMS) method to allow calculation of standard deviation z-scores. Growth data for 195 children with CP in Glasgow, UK, were retrieved and converted to z-scores using the CP reference as well as the combined World Health Organization and UK 1990 growth reference (UK-WHO).

RESULTS Compared to the UK-WHO reference, measurements diverged progressively with increasing severity, with mean height for GMFCS level V being close to the second UK-WHO centile. Compared with the CP reference, mean height and weight z-scores were between the 50th and 75th centiles for all severity levels, while body mass index was just below the 50th centile.

INTERPRETATION British children with severe CP seem relatively very small when their growth data are plotted on non-CP charts, but their data for weight and body mass index fit well to US CP charts and reasonably well for height. The LMS look-up tables will make it possible to calculate z-scores and produce charts in local formats.

Cerebral palsy (CP) is one of the most common physical disabilities in children, with a prevalence of around 2 per 1000 children.¹ It is characterized by a variable degree of motor and postural impairment due to a non-progressive insult to the developing brain, which is also commonly accompanied by cognitive or sensory impairment.² Health care professionals use growth charts as a tool for monitoring how a child is growing compared with children of the same age and sex, and to identify children whose weight or height falls significantly below normal centiles, which may indicate the need for investigation or treatment. It has been known for some time that children with severe CP do not grow or gain weight as expected for typically developing peers.³ CP is commonly associated with feeding difficulty, owing to oromotor impairment, affecting the ability to chew and swallow safely,⁴ and the extent of feeding difficulty has been shown to predict growth outcomes.⁵ The wider recognition of this has led to many children receiving gastrostomy tube feeding in recent years, with clear benefits for their state of nutrition and quality of life.^{6,7} However, despite gastrostomy feeding, many children with severe CP remain very small, leading to recognition that even with careful clinical nutritional monitoring

and intervention, children with severe CP grow slowly for intrinsic rather than nutritional reasons.

A large study of children with CP who had accessed the services provided by the California Department of Developmental Services within a 15-year period, 1988 to 2002, summarized the growth of 24 920 children and found clear gradients for height and weight between the most and the least severe.⁸ The same group used these data to develop growth charts for height, weight, and body mass index (BMI), specifically for children with CP aged 2 to 20 years.⁹ Charts showing centiles for height-for-age, weight-for-age, and BMI-for-age were statistically modelled using 141 961 measurements of height and weight. Specific charts were developed, for both sexes, for each of the five levels of the Gross Motor Function Classification System (GMFCS) for severity of CP motor involvement;¹⁰ level V, representing the most severe motor disability, was further stratified by the presence or not of a feeding tube. Thus, there were a total of 12 separate growth charts.

Although published in 2011, there has so far only been one published validation of the weight curves,¹¹ and their international relevance is unclear. Our aim, therefore, was to retrieve a growth data set for British children with CP

to explore how well they fitted the US CP charts compared with the mainstream UK charts.

METHOD

Patients

The NHS Greater Glasgow and Clyde Community Paediatric Services have a large caseload of children with CP, seen first usually to make the diagnosis and then monitored through the school years to coordinate their care needs. All contacts with children managed by Greater Glasgow and Clyde Community Paediatric Services were recorded in their Support Needs System electronic database. All children with a diagnosis of CP recorded within that database born between 1997 and 2013 were identified, and available weight and height data downloaded. All weights were recorded on electronic, clinical grade standing, sitting, or wheelchair scales. Standing height was measured where possible, usually using a wall-mounted measure with a rigid T-piece, or occasionally a rigid free-standing scale. Children who could not stand were measured using a flexible rule laid on the couch under the child. Lengths were not usually measured at all where children had fixed contractures to both legs, were too long for the measurer, or were too heavy to lift.

For children with any growth data, the child's consulting supervising community paediatrician was contacted and asked to notify the child's GMFCS level and whether they were tube fed. The growth records were also linked to a specialized CP database which included some, but not all, of the children managed by the service, where GMFCS level was recorded, but not tube feeding status.

The GMFCS levels were defined as follows.¹² Level I: walks without restrictions; limitations in more advanced gross motor skills. Level II: walks without assistive devices; limitations in walking outdoors and in the community. Level III: walks with assistive mobility devices; limitations in walking outdoors and in the community. Level IV: self-mobility with limitations; children are transported or use power mobility outdoors and in the community. Level V: self-mobility is severely limited even with the use of assistive technology, although not tube fed. Level V-TF: same severity as level V and tube fed.

Enteral feeding turned out to be poorly recorded, and some children started or stopped tube feeding as they got older. So, for our purposes, the two level V categories were merged and plotted in the level V non-tube fed charts. Once the data were matched to a GMFCS level, child identifiers were deleted and the analyses were undertaken on this anonymized data set. The analysis was classified as service evaluation, so no ethical permissions were required.

Further analysis of the US source data

The US CP charts were constructed using Generalized Additive Models for Scale and Shape (GAMLSS) and the Box-Cox power exponential distribution family¹³ as implemented with the GAMLSS package¹³ in the R language

What this paper adds

- Children with severe cerebral palsy (CP) seem relatively very small when their growth data are plotted on standard charts.
- The weight and body mass index data for UK children with CP fit well to US CP charts.
- UK children with CP seem tall when their height data are compared with US CP charts.
- It is now possible to calculate CP z-scores and produce charts in local formats.

(Vienna: R Foundation for Statistical Computing, 2016). The fitted chart centiles (from the 1st to the 99th) were tabulated by age in tenths of a year from 2 to 20 years, giving tables with 181 rows and 99 columns. There were separate tables of weight, height, and BMI by sex, for each of the GMFCS levels. The advantage of this approach was that the centiles were adjusted for distributional skewness and kurtosis, but the disadvantage was the lack of convenient software to convert the measurements and centiles to exact standard deviation z-scores.

For the present analysis, the tables were recalculated to match tables for the lambda-mu-sigma (LMS) method,¹⁴ using the LMSfit function in the sitar package (Tim Cole, London, 1.0.4 version, 2016). The LMS method corresponds to the GAMLSS Box-Cox Cole-Green family, a special case of the Box-Cox power exponential family that adjusts for distributional skewness, but not kurtosis. However, in practice, Box-Cox power exponential centiles are usually very similar compared to LMS/Box-Cox Cole-Green centiles, and any differences are restricted to the most extreme (i.e. top and bottom) centiles. This reanalysis converted the references to LMS tables compatible with LMSgrowth¹¹ software, which in turn allowed (1) individual measurements to be converted to z-scores, and (2) the GMFCS chart centiles to be adjusted to match the UK nine-centile format.¹⁵ It also meant that the GMFCS charts could be compared directly with the combined World Health Organization and UK 1990 growth reference (UK-WHO) as used in the UK for school-age children.¹⁶ A small pilot of manual plotting on the charts for GMFCS levels IV and V suggested that the fit to the charts was reasonable, but that data for a wider range of ages and severities were needed.

Analysis of data from the UK cohort

Anthropometric measures for children with known GMFCS levels were converted to z-scores using LMSgrowth software (UK Medical Research Council, 2012), compared to both the relevant GMFCS reference and the UK-WHO reference. These data were first analysed per measurement, as the larger numbers allowed examination of narrow age categories, as well as all the GMFCS levels. In addition, the z-scores for weight and height were averaged by child, along with the mean ages of measurement, and the analyses were then repeated for the within child means.

We defined the fit to either reference in terms of the discrepancy of the mean value from the expected value,

zero, as described in a recent paper:¹⁷ a poor fit being a discrepancy of greater than 0.67 standard deviations and a good fit being within 0.33 standard deviations.

We hypothesized that, compared with UK-WHO, children with mild CP would fit well on average, but that centiles would be progressively lower with greater CP severity, and with increasing age. Compared with the CP reference, we hypothesized that the children with CP would on average be close to average for all grades of severity, with no variation by age. However, we also had to consider the possibility that the CP weight and BMI z-scores would be below average, owing to selective weighing of children with poor weight gain.

RESULTS

There were 336 children coded as having CP in the database, born between 1997 (when growth was first recorded) and 2013. Of these, 293 had at least one measurement and 195 had a GMFCS level recorded. The remainder did not have a score entered on the database and their paediatrician had not replied to our request for this extra information. This provided 480 heights and 596 weights (see Table SI, online supporting information) with median (range) two (0–11) weights and two (0–15) heights per child, aged 2 to 17 years.

Using the UK-WHO reference, height and weight z-scores declined with increasing CP severity, with median height z-score for GMFCS level V close to the UK-WHO second centile (Fig. 1). In contrast, with the CP reference and the appropriate GMFCS level chart, median height and weight were between the 50th and 75th centiles for all GMFCS levels, while BMI was consistently close to the 50th centile. Table I shows the corresponding z-score means and standard deviations. In terms of formal criteria, the fit to the CP reference was good or acceptable (i.e. within 0.67 standard deviation) at all levels for weight and BMI, and for height at all GMFCS levels except III and V.

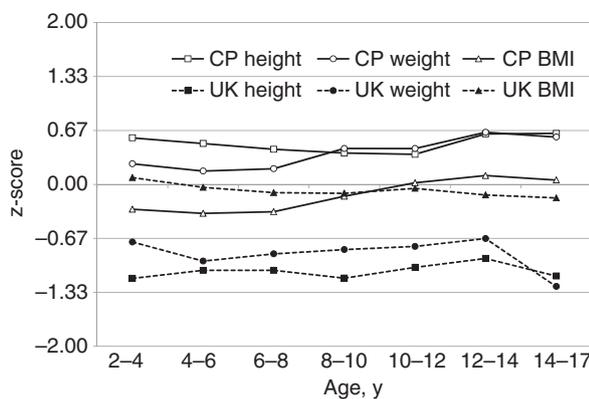


Figure 1: Fit of individual measurements to cerebral palsy and UK charts, by severity (GMFCS). BMI, body mass index; GMFCS, Gross Motor Function Classification System.

Using the UK-WHO, there was a poor fit for height from GMFCS levels II to V, for weight at levels IV and V, and BMI at level V. The standard deviations of the z-scores for the UK-WHO were usually greater than 1 (range 0.9–2), while for the CP reference they were less than 1 (range 0.5–1).

Compared with the UK-WHO charts, children with CP had lower height from age 2 years onwards, with little overall evidence of worsening with age. However, those with more severe CP were the most discrepant from the UK 1990 reference (Fig. 2) and this discrepancy tended to increase with age (Table II). In contrast, there was a trend to increasing weight and BMI z-scores with age in all severities compared with the CP reference (Table II). These analyses were repeated in the per-child data set and similar effects were seen (data not shown).

DISCUSSION

Recognizing the limited growth potential of many severely disabled children is important to avoid invasive feeding approaches when they are not needed. While some children will require gastrostomy feeding due to unsafe swallow, there is the risk that others are tube fed because of a misperception that they are nutritionally compromised. Recent studies have demonstrated that, when tube fed, these children often have very modest requirements¹⁸ and tend to become over-fat.¹⁹ Equally, it is important not to assume simply that all is well in children with CP and slow weight gain. What is needed is a valid reference for comparison and these charts seem to go a long way in providing this, although they can only serve as a description of how such children grow, rather than a standard of optimal growth.

Compared with the UK reference, the height and weight deficit of children with CP was very pronounced and present from age 2 years. To our surprise, the deficits increased only slightly with age, even in those with the most severe CP, which suggests that the slow growth trajectory in CP is set very early on. The fit to the UK reference was much better generally for BMI, although the data for children with the most severe CP still fitted poorly. In contrast, the fit to the California CP charts was mainly acceptable, although children tended to be somewhat taller in all GMFCS levels, and those with more severe CP also tended to be heavier. The fit for BMI was better and showed the closest fit for those with more severe CP, with mean values tending to be slightly below the 50th centile.

There were limitations in this study. Not all children with CP had growth data recorded electronically, and many had only one or two data points. Working within a clinical system and dependent on the good will of many paediatricians, we were only able to identify a GMFCS level for two-thirds of the children, but this should not have introduced any systematic bias. It still yielded data on nearly 200 children, with a median of two weights and two heights per child, and spanning the whole of childhood. The relative sparsity of the data per child will inevitably

Table 1: z-scores for height, weight, and body mass index (BMI) based on UK 1990 and US cerebral palsy references, by Gross Motor Function Classification System (GMFCS) level

Individual measurements	N	UK 1990 reference						US cerebral palsy reference						
		Height		Weight		BMI		Height		Weight		BMI		
GMFCS level	Heights	Weights	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
I	150	157	-0.63	1.07	-0.30	1.23	0.09	1.28	0.38	0.54	0.07	0.79	-0.34	0.67
II	131	135	<u>-1.03</u>	1.28	-0.37	1.50	0.37	1.38	0.40	0.61	0.25	0.94	-0.13	0.73
III	60	72	<u>-0.86</u>	1.14	-0.59	1.53	0.07	1.59	<u>0.80</u>	0.56	0.50	0.86	-0.12	0.79
IV	56	81	<u>-1.79</u>	1.43	<u>-1.63</u>	1.95	-0.41	1.96	<u>0.49</u>	0.62	0.20	1.02	-0.18	0.82
V	83	151	<u>-1.68</u>	1.56	<u>-1.52</u>	1.77	<u>-0.80</u>	1.75	<u>0.71</u>	0.62	0.62	0.85	-0.26	0.74
Average per child	N of children													
I	52		-0.46	0.90	-0.22	1.08	0.03	1.15	0.48	0.46	0.13	0.71	-0.38	0.61
II	43		<u>-0.81</u>	1.25	-0.35	1.38	0.25	1.30	0.51	0.60	0.26	0.86	-0.18	0.69
III	26		<u>-1.10</u>	1.05	-0.59	1.43	0.11	1.39	<u>0.67</u>	0.50	0.50	0.80	-0.11	0.68
IV	28		<u>-1.70</u>	1.34	<u>-1.38</u>	1.85	-0.32	1.89	<u>0.54</u>	0.58	0.35	0.97	-0.12	0.82
V	46		<u>-1.84</u>	1.60	<u>-1.69</u>	1.61	<u>-0.86</u>	1.71	0.66	0.62	0.54	0.70	-0.24	0.66

Bold type indicates good fit to standard (standard deviation [SD]<0.33 discrepancy from expected 0); underlined type indicates poor fit (SD>0.67 discrepancy).

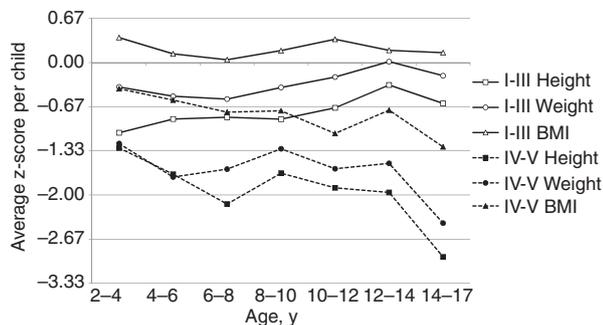


Figure 2: Fit of individual measures to UK 1990 charts, by age and severity (Gross Motor Function Classification System [GMFCS]). Roman numerals indicate GMFCS level. BMI, body mass index.

raise concerns about their representativeness, with the risk that more measurements were collected at times when there were concerns about growth or weight gain. Thus, in using single measurements, there was a risk of bias due to children with poor growth being measured more often than others.²⁰ When using average values per individual child, this bias was minimized but the numbers were then small. However, analysis of the data using both methods reassuringly yielded very similar results. We had very few data for later adolescence, at which point they may have been harder to measure. However, the data points we had at these ages were consistent with earlier ages.

The standard deviations of the z-scores based on the UK-WHO reference were all greater than the expected value of 1, which may reflect a non-healthy sample being compared with a healthy reference. In contrast, when compared to the CP reference, the standard deviations were all less than 1, suggesting less than the expected level of variation. Taken together with the relatively high height and weight z-scores, this suggests that UK children are bigger and less variable in anthropometric measures than the

reference Californian children. Measurement of height and length is often challenging in children with CP, so that these differences might reflect differences in measurement method. The equipment used in both settings was not standardized and (in the UK) the most severely disabled, older children tended not to be measured at all. Contractures used to significantly limit measurement in CP, but these are now much less common owing to early physiotherapy and splinting. However, these factors would be expected to differentially affect length for the children with the most severe CP, when in fact mean heights/lengths were higher for all severities.

Part of the explanation might be related to general demographics. The Californian population was more heterogeneous for ethnicity, with a large proportion of Hispanic individuals who tend to be shorter than non-Hispanic white persons of the same age.²¹ To our knowledge, differences in CP growth by ethnicity have not been studied directly, but a recent study by the Surveillance of Cerebral Palsy in Europe did find that anthropometric measures differed across countries in a pattern that seemed to relate to differing rates of enteral feeding.²² Beyond general demographic considerations, it should be recognized that the British children were predominantly born and managed in the years 2000 to 2010, around 10 years after most of the Californian children were measured. Studies from both the US and the UK^{23,24} have documented significant trends towards increased weight and BMI of children as measured in general paediatric practices from the early 1990s. In addition, the study period is recognized as one of increased awareness of the risks of malnutrition in children with CP. However, again this trend is seen consistently in all severities, particularly for height, and it seems unlikely that children with milder CP will have previously experienced undernutrition in childhood. However, many of these children with all severities will have been born preterm, so it is possible that these differences could reflect better recent nutritional care as neonates.

Table II: z-scores for individual height, weight, and body mass index (BMI) based on UK 1990 and US cerebral palsy references, by age and severity

	Age, y	UK 1990 reference						US cerebral palsy reference					
		Height		Weight		BMI		Height		Weight		BMI	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
GMFCS level I–III	2–4	–1.06	1.17	–0.37	1.27	0.38	1.22	0.51	0.56	0.26	0.83	–0.26	0.57
	4–6	–0.85	1.05	–0.51	1.43	0.13	1.51	0.49	0.49	0.14	0.92	–0.37	0.74
	6–8	–0.83	1.14	–0.55	1.43	0.04	1.34	0.42	0.50	0.10	0.87	–0.34	0.72
	8–10	–0.86	1.12	–0.38	1.41	0.18	1.38	0.27	0.56	0.18	0.85	–0.13	0.76
	10–12	–0.68	1.27	–0.22	1.80	0.35	1.67	0.28	0.70	0.25	1.07	0.07	0.89
	12–14	–0.34	1.40	0.01	1.45	0.18	1.37	0.62	0.79	0.46	0.85	0.03	0.71
	14–17	–0.62	1.28	–0.20	0.96	0.15	1.16	0.68	0.80	0.43	0.67	0.03	0.69
p^a	0.05		0.14		0.76		0.70		0.15		0.001		
IV–V	2–4	–1.29	1.44	–1.22	1.61	–0.40	1.68	0.70	0.62	0.24	0.88	–0.38	0.67
	4–6	–1.68	1.83	–1.73	2.31	–0.57	2.11	0.58	0.77	0.20	1.14	–0.33	0.83
	6–8	–2.14	1.35	–1.61	1.45	–0.75	2.12	0.51	0.57	0.41	0.71	–0.34	0.83
	8–10	–1.67	1.49	–1.30	1.87	–0.73	1.29	0.71	0.63	0.75	0.93	–0.18	0.61
	10–12	–1.89	1.14	–1.60	2.09	–1.07	2.06	0.62	0.51	0.73	1.04	–0.10	0.89
	12–14	–1.96	1.37	–1.52	1.50	–0.72	2.01	0.68	0.64	0.88	0.68	0.25	0.85
	14–17	–2.94	1.32	–2.43	1.52	–1.27	2.11	0.44	0.55	0.75	0.65	0.14	0.81
p^a	0.07		0.04		0.13		0.88		<0.001		0.001		

^aLinear regression. GMFCS, Gross Motor Function Classification System; SD, standard deviation.

The Californian reference data showed that children who were tube fed were both heavier and taller than children with equally severe disabilities who were not, which suggests that at least some of the growth deficit in severe CP reflects a nutritional deficit.⁸ In our sample, we could not reliably identify tube feeding status and the combined UK GMFCS level V group showed an acceptable fit to the GMFCS level V non-tube fed California reference. Further research is necessary to validate the use of charts that are stratified by mode of feeding and to clarify how to classify children who start or cease enteral feeding over time.

Surprisingly, the best fit for the UK children with CP was to the BMI charts. BMI is not widely used in this population but it can be highly illuminating in small children where there is concern about possible undernutrition. However, it is the measure most prone to error and in clinical practice we would always recommend use of skin-folds as well, as a more direct assessment of fat stores.

In conclusion, UK children with severe CP seem relatively very small when their growth data are plotted on standard charts. Their data fit the US CP charts much

better, although tending to be heavier and taller than average. Presenting the US CP charts as LMS tables will make it possible to calculate z-scores specific to GMFCS level, as well as to create paper charts using local chart formats.

ACKNOWLEDGEMENTS

We are grateful to the Glasgow community paediatricians who supplied GMFCS scores for their patients and to NHS Greater Glasgow and Clyde Information services for providing the linked GMFCS scores. There was no specific funding support for this analysis. TJC is funded by UK Medical Research Council grant MR/M012069/1. JB headed the team who developed the CP charts, and TJC constructed the UK 1990 growth reference. Neither of them derive income from their charts. The other authors have stated that they had no interest that could be perceived as posing a conflict or bias.

SUPPORTING INFORMATION

The following additional material may be found online:

Table S1: Number of individual measurements per GMFCS level, by age group

REFERENCES

- Sellier E, Platt MJ, Andersen GL, et al. Decreasing prevalence in cerebral palsy: a multi-site European population-based study, 1980 to 2003. *Dev Med Child Neurol* 2016; **58**: 85–92.
- Rosenbaum P, Paneth N, Leviton A, et al. A report: the definition and classification of cerebral palsy April 2006. *Dev Med Child Neurol Suppl* 2007; **109**: 8–14.
- Stallings VA, Charney EB, Davies JC, et al. Nutritional status and growth of children with diplegic or hemiplegic cerebral palsy. *Dev Med Child Neurol* 1993; **35**: 997–1006.
- Motion S, Northstone K, Emond A, et al. Early feeding problems in children with cerebral palsy: weight and neurodevelopmental outcomes. *Dev Med Child Neurol* 2002; **44**: 40–3.
- Fung EB, Samson-Fang L, Stallings VA, et al. Feeding dysfunction is associated with poor growth and health status in children with cerebral palsy. *J Am Diet Assoc* 2002; **102**: 361–73.
- Sullivan PB, Juszczak E, Bachlet AM, et al. Gastrostomy tube feeding in children with cerebral palsy: a prospective, longitudinal study. *Dev Med Child Neurol* 2005; **47**: 77–85.
- Craig GM, Carr LJ, Cass H, et al. Medical, surgical, and health outcomes of gastrostomy feeding. *Dev Med Child Neurol* 2006; **48**: 353–60.
- Day SM, Strauss DJ, Vachon PJ, et al. Growth patterns in a population of children and adolescents with cerebral palsy. *Dev Med Child Neurol* 2007; **49**: 167–71.
- Brooks J, Day S, Shavelle R, et al. Low weight, morbidity, and mortality in children with cerebral palsy: new clinical growth charts. *Pediatrics* 2011; **128**: e299–307.

10. Palisano R, Rosenbaum P, Walter S, et al. Development and reliability of a system to classify gross motor function in children with cerebral palsy. *Dev Med Child Neurol* 1997; **39**: 214–23.
11. Araujo LA, Silva LR. Anthropometric assessment of patients with cerebral palsy: which curves are more appropriate? *J Pediatr (Rio J)* 2013; **89**: 307–14.
12. Rosenbaum PL, Walter SD, Hanna SE, et al. Prognosis for gross motor function in cerebral palsy: creation of motor development curves. *JAMA* 2002; **288**: 1357–63.
13. Rigby RA, Stasinopoulos DM. Generalized additive models for location, scale and shape. *J R Stat Soc C* 2005; **54**: 507–54.
14. Cole TJ. The LMS method for constructing normalized growth standards. *Eur J Clin Nutr* 1990; **44**: 45–60.
15. Cole T. Do growth chart centiles need a face lift? *BMJ* 1994; **308**: 641–2.
16. Wright CM, Williams AF, Elliman D, et al. Using the new UK-WHO growth charts. *BMJ* 2010; **340**: c1140.
17. Levin D, Marryat L, Cole TJ, et al. Fit to WHO weight standard of European infants over time. *Arch Dis Child* 2016; **101**: 455–60.
18. Vernon-Roberts A, Wells J, Grant H, et al. Gastrostomy feeding in cerebral palsy: enough and no more. *Dev Med Child Neurol* 2010; **52**: 1099–105.
19. Sullivan PB, Alder N, Bachlet AM, et al. Gastrostomy feeding in cerebral palsy: too much of a good thing? *Dev Med Child Neurol* 2006; **48**: 877–82.
20. Wright CM. Who comes to be weighed: an exception to the inverse care law. *Lancet* 1997; **350**: 642.
21. Fryar CD, Gu Q, Ogden CL. Anthropometric reference data for children and adults: United States, 2007-2010. *Vital Health Stat* 2012; **11**: 1–48.
22. Dahlseng MO, Andersen GL, DA Graca Andrada M, et al. Gastrostomy tube feeding of children with cerebral palsy: variation across six European countries. *Dev Med Child Neurol* 2012; **54**: 938–44.
23. Lee JM, Pilli S, Gebremariam A, et al. Getting heavier, younger: trajectories of obesity over the life course. *Int J Obes (Lond)* 2010; **34**: 614–23.
24. van Jaarsveld CH, Gulliford MC. Childhood obesity trends from primary care electronic health records in England between 1994 and 2013: population-based cohort study. *Arch Dis Child* 2015; **100**: 214–9.