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Original Article

Designing new UK-WHO growth charts: implications for health staff use and understanding of charts and growth monitoring

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Abstract

New pre-school UK charts have been produced incorporating the new World Health Organization growth standards based on healthy breastfed infants. This paper describes the process by which the charts and evidence-based instructions were designed and evaluated, and what it revealed about professional understanding of charts and growth monitoring. A multidisciplinary expert group drew on existing literature, new data analyses and parent focus groups as well as two series of chart-plotting workshops for health staff. The first series explored possible design features and general chart understanding. The second evaluated an advanced prototype with instructions, using plotting and interpretation of three separate scenarios on the old charts, compared with the new charts. The first plotting workshops (46 participants) allowed decisions to be made about the exact chart format, but it also revealed widespread confusion about use of adjustment for gestation and the plotting of birthweight. In the second series (78 participants), high levels of plotting inaccuracy were identified on both chart formats, with 64% of respondents making at least one major mistake. Significant neonatal weight loss was poorly recognized. While most participants recognized abnormal and normal growth patterns, 13–20% did not. Many respondents had never received any formal training in chart use. Growth charts are complex clinical tools that are, at present, poorly understood and inconsistently used. The importance of clear guidelines and formal training has now been recognized and translated into supporting educational materials (free to download at http://www.growthcharts.rcpch.ac.uk).

Keywords: growth assessment, health services research, growth charts, prematurity.

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Background

Growth is a vital marker of nutrition and health, and accurate plotting of measurements on growth charts is essential to allow it to be assessed. Previous studies conducted on understanding of the charts have focused primarily on parents, predominantly in developing countries, assuming that professional understanding is unproblematic (Ben Joseph *et al*. 2007; Roberfroid *et al*. 2007), yet in one study of UK primary care doctors, half of them felt unable to detect normal growth while less than 2/3 of paediatricians felt competent in detecting abnormal growth (Wallace and Kosmala-Anderson 2006). Growth charts can be an important 'objective' tool in raising difficult discussions with parents, for example, about overweight (Edvardsson *et al*. 2010), but the positive impact of this relies on accuracy of interpretation.

One UK study found 'confusion in the knowledge and practice base of health professionals' leading to the possibility of both inappropriate referrals and failure to identify real problems (Spencer *et al*. 1996).

The new World Health Organization (WHO) growth standards for children aged 0–5 years are based solely on healthy, breastfed infants living in optimal circumstances. These for the first time provide a standard of how all children *should* grow (WHO MGRSG & de Onis 2006). This standard has now been adopted in the UK, in place of the UK national reference (Freeman *et al*. 1995) for children under 4 years of age, while retaining the UK 1990 preterm and birth centiles. The report recommending adoption (SACN 2008) also highlighted the low level of staff understanding of charts. The UK Royal College of Paediatrics and Child Health (RCPCH) was thus commissioned by the Department of Health (England) to design new charts with evidence-based instructions and educational materials. A multidisciplinary expert group was formed to complete the work within a tight timescale (12 months). It comprised five paediatricians, two academic health visitors, a medical statistician and a breastfeeding researcher. The charts were published in May 2009 (free to download at http://www.growthchart.rcpch.ac.uk) and have been described elsewhere (Wright *et al*. 2010).

The charts were produced using an iterative action research model, which, aside from informing the design process, shed important light on how charts and weight monitoring are understood and used. The aim of this paper is to describe what were the lessons learned from the design process, what the evaluation of the charts revealed about professional understanding of growth charts and how this informed the final design.

Method

The expert group considered the physical design and layout simultaneously with the chart instructions. The design process was informed by product testing with health staff plotting workshops, described in this paper, as well as new data analyses, a stakeholder consultation and parent focus groups (to be described elsewhere).

Chart design

What was needed was a set of small individual charts for the personal child health record (PCHR). The PCHR is held by all parents in the UK and used mainly by health visitors: public health nurses who undertake most well child monitoring in the UK. In addition, a composite chart was required for specialist practice showing weight, height and head circumference together on each page, with one page up to age 1 year and a second for 1–4 years.

Like the previous British (UK 1990) charts (Freeman *et al*. 1995), the new charts used the nine centile format (Fig. 1), with the centiles spaced two-thirds of a standard deviation apart and including two extreme centiles (0.4th and 99.6th) (Cole 1994). The main changes to the design were around birth, with a separate preterm section (using UK 1990 reference data), and an infancy chart using WHO data from age 2 weeks (SACN 2008). The design needed to be photocopied clearly with a minimum amount of text overlying the plotting area. The expert group produced a design specification, and the detailed design work was undertaken by a specialist chart printing firm (Harlow Printing, South Shields, UK) led by JS who worked closely with the expert group throughout. The details

Key messages

- Growth charts are widely used in children worldwide and the newly published WHO charts now provide a standard for how all children under the age of 5 should grow. However, the few previous evaluations of chart use suggest that charts are poorly understood.
- Growth charts are complex clinical tools that are used inconsistently, with poor understanding of adjustment for gestation and high levels of plotting errors. Clear chart designs supported by unambiguous evidence-based instructions should help, but formal training is also important.

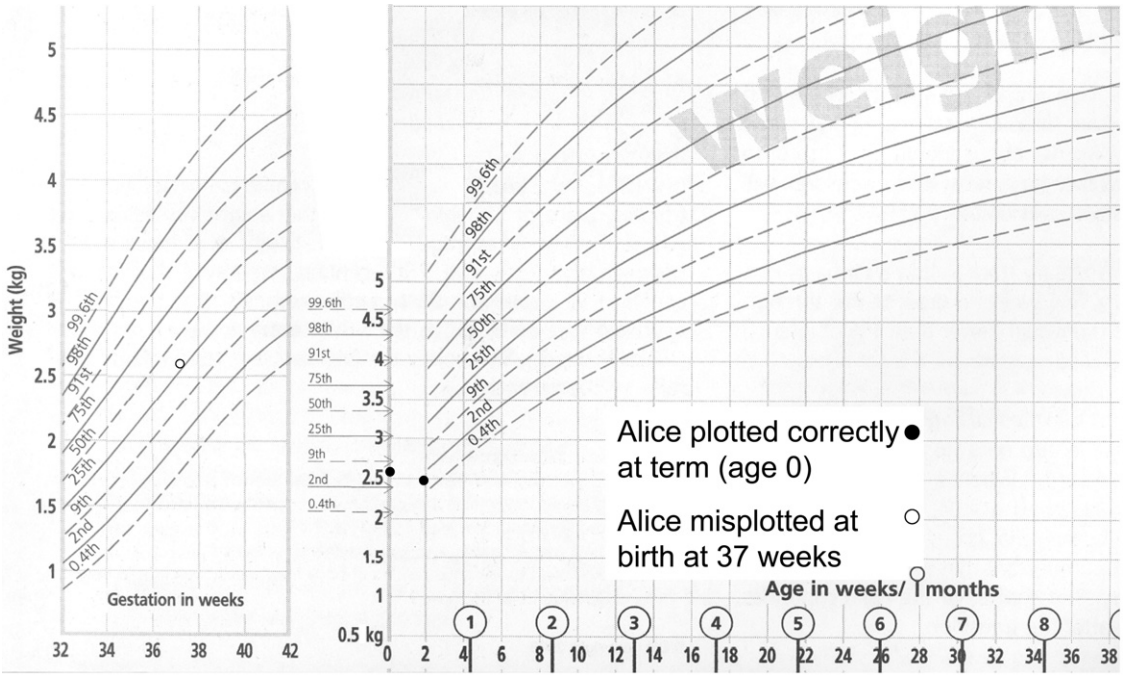

Fig. 1. Extract from final composite chart. Growth data for Alice plotted correctly (black dots) at age 0 showing birth centile between 2nd and 9th with decline of one centile space to between 0.4th and 2nd centile at age 2 weeks. When birthweight plotted incorrectly at 37 weeks' gestation (white dot) this incorrectly suggests a decline of 2.5 centile spaces between birth and 2 weeks.

of the design changes around birth, and the manipulation of the data required are described elsewhere (Cole *et al*. 2011).

Health staff chart-plotting workshops

These were held at two stages in the design process: the first was to test a variety of new design features, and the second was to evaluate a more advanced prototype. Groups were convened via professional and teaching networks and were conducted by two facilitators experienced in qualitative research (MS and LS). Each group opened with an introduction, then participants undertook various plotting exercises using a workbook that was retained for analysis. The facilitators observed participants during the exercises and, at the end, the participants discussed their impressions of the charts and their understanding of the exercises. Sessions were recorded and transcribed then summarized. The work constituted service evaluation and did not require ethical approval.

First series

The overall aim of these workshops was to test understanding of the new design features and to assess their possible impact on plotting and interpretation. The participants worked through four scenarios that required points to be plotted on both the new prototype and the existing UK 1990 charts (Table 1). As the chart versions used in these groups were so different from the final charts, only simple analyses of the quantitative data collected were undertaken.

Second series

The purpose of this series was to test the overall accuracy of plotting and reading of the new charts, with emphasis on new elements, and areas of known difficulty. The participants undertook three plotting exercises (Table 2). The first two (John 2 and George 2) were permutated, so that half the participants plotted each on either the old or the new charts, to allow comparison. George was plotted on PCHR charts in

new and old format in five of the workshops, but in two workshops, the new composite chart was used. A third scenario (Kayleigh) was plotted only on the new composite chart, specifically to test a new height predictor (to be described elsewhere) and a body mass index (BMI) lookup (Cole 2002).

Analysis

In series two, the participants' record of their plotted values were coded as correct if within 1/4 centile space [0.17 standard deviation (SD)] of the model answer. For each scenario, the proportion of plots that were all correct and the proportion that was more than 3/4 centile (0.5 SD) wrong was calculated, as long as the participant had plotted at least two-thirds of the measurements provided.

Table 1. Scenarios used in first series of plotting workshops

Scenario and data provided	Activity
George (1) is a healthy child, born at 42 weeks' gestation, weight 4 kg; 3.5 kg (12.5% loss) at 2 weeks.*	Data plotting and interpretation
Alice is a healthy child, born at 37 weeks' gestation, weight is 2.5 kg at birth and 2.45 kg at 2 weeks.*	Data plotting and interpretation
John (1) is a healthy child, born at 34 weeks' gestation, weight is >50th centile with steady weight gain to chronological age of 3 months.	Data plotting and interpretation
Jenny: series of plotted lengths and height stable across length/height disjunction, but dropping from 25th to 2nd between age 2 years and 7 months and 3 years and 9 months.	Interpretation only

*Permutated, with half of participants plotting on new charts, half on UK 1990.

Results

Chart-plotting workshop participants

In the first series, five workshops were held in three British centres (Newcastle, Birmingham and London) in July 2008 with 46 participants [13 (28%) health visitors, 11 (24%) nursery nurses or non-medical children's workers, 9 (20%) secondary care paediatric nurses, remainder are students or not specified]. The second series comprised seven workshops held in September 2008 in three centres (Glasgow, Birmingham and London) with 78 participants [35 (45%) health visitors, 15 (19%) dieticians, 8 (10%) paediatricians, remainder are various other nurses]. Not all participants completed all the plotting exercises, but each was completed by a minimum of 65 participants.

Gestational adjustment

The first series of workshops revealed confusion and inconsistency about when to apply gestational adjustment. John, an infant born at 34 weeks' gestation (see Table 1) was plotted correctly at birth, but thereafter only around half the respondents plotted at the gestationally corrected age (19/34 at age 2 weeks, 13/24 at age 8 weeks, 11/22 at age 3 months). In the

Table 2. Scenarios used in second series of plotting workshops

Scenario	Interpretation	To test correct use of	To test recognition of
John (2) is a healthy child, born at 34 weeks' gestation. Six data points*	Fallen >2 weight centile spaces (1.33 SD) by age 6 months	Preterm section Gestational correction	Weight faltering
George (2) is a healthy child, born at 42 weeks' gestation. Four data points*	12.5% loss at aged 2 weeks, back to 50th centile by 8 weeks	Plotting at age zero	Neonatal weight loss and catch up weight gain
Kayleigh was born at term, and at 3 years, mother was worried about short stature. Six data points and two BMIs to lookup	Steady growth BMI 91st at 26 months, >99.6th at 42 months	BMI lookup	Normal growth trajectory and overweight at age 3

BMI, body mass index; SD, standard deviation.
*Permutated, with half of participants plotting on new charts, half on UK 1990.

Table 3. Responses from second series of plotting workshops for John 2 (34 weeks' gestation neonate, with weight faltering, age 6 months)

	UK 1990 PCHR	New PCHR
Number of respondents	39	38
All plots completely correct	3% (1)	0
All plots broadly correct*	67% (26)†	37% (14)
Gestational adjustment still applied at		
8 weeks	92% (36)	92% (35)
6 months	86% (32)	65% (24)
Concerned about weight gain at		
8 weeks (when normal)	13% (5)	18% (7)
6m (weight faltering)	80% (30)	81% (30)

Values are % (number) of participants.
PCHR, personal child health record; *All plotted points within >3/4 centile space (0.5 standard deviation) of the correct plotted position for each data point. †$P < 0.009$ compared to new chart, all other comparisons $P > 0.05$.

second series, with new instructions and pre-teaching on gestational adjustment, a much higher proportion continued gestational adjustment (see Table 3). However, there were more misplots in this series compared with the term scenario, even where gestational adjustment of age had been applied, and these were significantly more common in the new format.

Gestational adjustment was also used inappropriately for term infants. In the first series, 45% (10/22) of the participants using the UK 1990 charts plotted Alice's birthweight at 37 weeks rather than term, which yields very different centiles (see Fig. 1), and 5/20 (25%) also plotted gestationally adjusted age at 2 weeks. It became evident that health professionals were using different definitions of 'preterm', with some including all infants born before 38 completed weeks. Even the design team were not clear at the outset whether birth data for term infants should be plotted at exact gestation or all at age 0, but this was resolved by a modelling exercise (Cole *et al*. 2011) that demonstrated that adjustment at birth only would produce centile shifts at the extremes of gestation between birth and 2 weeks. Thus, in the second series, participants were advised to plot all term births at 'age zero', and the great majority did so correctly (Table 4).

Recognition of normal and abnormal growth patterns

In the second series, when plotting George, who showed a 12.5% weight loss between birth and 2 weeks, only a few respondents rated this as very concerning, and only half would have referred either to a breastfeeding counsellor or paediatrician, though those using the new chart format were more likely to be concerned (Table 4). Discussion revealed that for some professional groups (paediatricians, midwives), the use of 10% as a threshold for concern was standard. In contrast, heath visitors rarely calculated percentage weight loss and did not see this weight loss as worrying, especially as the baby was breastfeeding.

Most second series participants did recognize both normal growth patterns and faltering weight gain later in infancy, but up to a fifth of the participants did not recognize it (Tables 3,4).

Chart layout and presentation

Early parental focus group work revealed that parents tend to expect all children to grow along the 'bold line', so a decision was made to avoid emphasizing the 50th centile. This was potentially confusing, and three different combinations of line and label were explored before satisfactory clarity was achieved (see Fig. 1). The first set of plotting workshops were also used to arrive at the optimum grid size for the length/height scale, using timed plotting exercises for two different grids, and to identify the preferred weight and folding of the card used. The new composite design has a centile discontinuity when the standard changes from length to height at age 2 years, at which point the centile lines drop slightly. It was feared that staff would find this challenging, but this proved not to be the case.

Use of the BMI lookup

The composite chart includes a lookup that allows the BMI centile to be read without calculation, once height and weight centile are known (Cole 2002). The majority of the participants used this successfully for

Table 4. Responses from second series of plotting workshops for George 2 (42 weeks' gestation infant with 12.5% neonatal weight loss)

	UK90 PCHR	New PCHR	New composite
Number of respondents	37	28	11
All plots completely correct	41% (15)	46% (13)	18% (2)
All plots broadly correct*	84% (31)	75% (21)	55% (6)
Birthweight plotted at term/age zero	97% (36)	100%	91% (10)
Rating of neonatal weight loss			
Very concerned	14% (5)†	29% (8)	46% (5)
Not concerned	8.3% (3)	18% (5)	0% (0)
Would refer to breastfeeding counsellor or paediatrician	54% (20)	44% (12)	82% (9)

Values are % (number) of participants.
PCHR, personal child health record; *All plotted points within >3/4 centile space (0.5 standard deviation) of the correct plotted position for each data point. †$P = 0.04$ compared with new charts.

Table 5. Responses from second series of plotting workshops for Kayleigh (3-year-old child)

	New composite
Number of respondents	65
All plots completely correct	41% (32)
All plots broadly correct*	89% (58
Recognizes growth is normal	82% (61)
BMI centile readings	
Both correct	59% (40)
Both within 3/4 centile space	72% (49)
Neither correct	10% (7)
Neither within 3/4 centile space	7% (5)
Recognizes overweight	
Age 2	30% (21)
Age 3	94% (67)

Values are % (number) of participants.
BMI, body mass index; *All plotted points within >3/4 centile space (0.5 standard deviation) of the correct plotted position for each data point.

one or both ages, but even so, the great majority only rated the child as overweight once above the 99.6th centile for BMI (Table 5).

Overall plotting accuracy

In the second series of plotting workshops, plotting mistakes were common on both the new and the old charts (Tables 3–5). A majority made at least one mistake in each scenario, although for George and Kayleigh, a majority plotted all points within 3/4 centile space of the correct plot. Overall, only 22/61 (36%) made no major mistakes in any scenario, and 19 (31%) made at least one mistake in each scenario. There was a trend to more mistakes where George was plotted on the composite charts, but numbers were small and plotting of Kayleigh, which was also on the composite chart, was the most accurate.

There was no trend to any professional group being more or less accurate, but numbers in most subgroups were small. In order to improve the accuracy of plotting by age, the labelling of weeks and months on the new chart had been made larger and more distinct. Every group made spontaneous appreciative comments about this. However, in this series, it became evident that the centile line labels had the potential to be ambiguous and were further improved before the charts were finalized (Fig. 1).

Drafting the instructions and educational materials

These needed to be concise enough to fit on the back of the charts (two pages of A4). The content was formed by the first series of plotting workshops as well as existing published evidence and official guidelines (Wright *et al*. 2010). These draft instructions were then included in the final prototype composite chart and thus tested in the second series of plotting workshops. They also informed the summary information provided for parents with the PCHR charts.

It was obvious from the workshops that clear definitions of 'term' and 'preterm' were required, as well as unambiguous guidance about when gestational adjustment should be applied. Guidance was

also required to clarify the importance of reviewing neonatal weight loss. A system of describing the centile position of a plotted point was developed (Wright *et al*. 2010), after two participants found themselves describing the same plotted point as 'below the 75th centile' and 'above the 50th centile', respectively. A need for clear recommendations for measurement frequency was recognized. Comments about excessive weighing frequency were made: 'it becomes a habit' and 'they (parents) become competitive about the gains'. A wide variation in length measurement practice was identified. Many districts never measured in primary care, but others did so frequently, although often with poor equipment or technique. Arriving at realistic but clinically safe instructions was thus challenging and this section in particular was critically reviewed by the expert group and underwent many drafts before agreement was reached.

These instructions formed the base curriculum for the supporting educational materials. Many participants in the plotting workshops remarked that they had learned about chart use only through observation in clinical placements. Different individuals had learnt widely varying conventions for gestational correction, centile terminology and what constituted normality. One participant remarked: 'I was made aware through this session that people interpret growth charts differently'. Another summed up: 'I just think nobody should be able to start plotting before they have had training – I think this would be a disaster waiting to happen'. A majority of participants stated that they would welcome training, preferably face to face, rather than online, as the opportunity to ask questions and have a discussion was valued.

Discussion

The process by which these charts were produced was, we believe, unique. A multidisciplinary expert group drew on existing literature, new data analyses and parent focus groups as well two series of chart-plotting workshops for the health staff. The plotting group model proved popular, and the participants remarked positively on the inclusion of practicing clinicians in the design. What we have learned about chart users' problems with plotting and interpretation would be of relevance to anyone using or teaching about charts, as well as for any country or group updating or redesigning their charts.

A strength of this programme was the high level of consultation with chart users. The design group devoted as much attention to the exact wording of the instructions as to the chart layout itself and the dynamic development process then allowed us to check and refine these with subsequent plotting workshops and stakeholders. Involvement of members of the expert group facilitating the workshops allowed them to experience feedback at first hand. The effect of this and the tight timescale created an intense immersion in the work. A limitation of the short timescale was that those evaluating the prototypes were entirely unfamiliar with them. Also, because of the iterative design process, the final version incorporating all refinements identified in the plotting workshops has not been formally evaluated.

Recent studies have found that parents are likely to rate growth along or above the 50th centile as most desirable (Sachs *et al*. 2006; Woolford *et al*. 2007; Ben Joseph *et al*. 2009; Laraway *et al*. 2010), which supports our decision to deemphasize the 50th centile, even if staff will need to familiarize themselves with this. In fact, there was little evidence that the unfamiliar format resulted in greater inaccuracy, except for preterm infants. What was surprising were the high levels of plotting errors identified on both formats. Growth monitoring in the UK relies heavily on nurses, but there was no evidence in this study that the doctors and dieticians included were any more accurate. The participants had limited time to complete the exercises, which may have affected their accuracy, but this mimics the real world situation. The high levels of error will reflect both the actual plotting accuracy and the highly variable terminology used to describe the plotted point. In this study, a significant minority expressed concern about normal growth patterns, while others had no concern about deviant patterns. This is in keeping with another small UK study (Spencer *et al*. 1996).

Some inaccuracy seemed to result from inconsistent prior advice. This was particularly so when dealing with variation in gestation at birth, which was

a major source of uncertainty for participants, as well as producing the most plotting errors. Only when we attempted to draft instructions and watched workshop participants follow them could we appreciate how hard this is to explain and how easy it is to confuse. These findings led us to appreciate the need to state clear and rigid definitions of term and preterm as well as how long allowance for prematurity should continue.

Inter-professional differences were apparent only in the recognition of early weight loss. Only 5–7% of infants ever lose 10% or more of birthweight (Macdonald *et al*. 2003; Wright & Parkinson 2004). Doctors and midwives were alert to this and recognized the possibility of feeding or medical problems. However, health visitors, who deal less with very young infants, seemed to be more concerned that any intervention might interfere with breastfeeding. The training package now emphasizes the importance of recognizing 10% weight loss and the research that suggests that early weighing and identification of feeding problems does not undermine breastfeeding (McKie *et al*. 2006).

The participants recognized that parents often request weighing more often than is necessary or desirable, but that weighing was often used as a passport to health advice and care. This signalled the need for wording in both professional instructions and parental information to emphasize that parents could still see their health visitor without having the baby weighed.

We hope that future work might formally assess professional use and understanding of the charts after they have been in regular use, with larger numbers of professional subgroups involved. In the meantime, the RCPCH plan to undertake annual reviews of feedback about the charts, solicited via their web site and received during training sessions.

Conclusions

Growth charts are a complex clinical tool that are poorly understood and inconsistently used. Clarity of design is important, but arguably it is even more important to have clear unambiguous rules for use, as opposed to general guidelines. Including professionals not just in consultation but also in practical testing of charts adds immeasurably to the process of designing charts, instructions and educational materials. The training needs identified in the plotting workshops have now been fed into the process of creating free-to-download supporting educational materials (http://www.growthcharts.rcpch.ac.uk) and training of trainers. However, until time is set aside to train all staff and incorporate this topic into all student curricula, chart use is likely to remain inaccurate and potentially misleading.

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Conflicts of interest

John Short is employed by Harlow Printing who supply the UK-WHO charts commercially. None of the other authors have any commercial interest in the charts or other conflicts of interest.

Contributions

CW was academic lead for the whole design project, and RM and MS also sat on the RCPCH expert group. MS and LS ran and analysed the plotting groups, with help from RM; KC coded and entered the quantitative data. JS oversaw the graphic design and advised on details of chart design and use. CW undertook the quantitative analyses and, with MS, drafted the article, with help from all the other co-authors.

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