Institution: University College London

Unit of Assessment: 2 - Public Health, Health Services and Primary Care

Title of case study: Redesigning children's growth charts

1. Summary of the impact

Research at the UCL Institute of Child Health underpinned the update in 2009 of children's growth charts, which allow for more accurate determination of a child's growth pattern and provide better tools for assessing possible weight problems in children. The new charts are now in universal use in the UK for children from birth to 18 years of age, including preterm babies. Having been quickly adopted, they now account for 90% of all growth chart sales. Modified versions of the charts are in use in Ireland and New Zealand. In the UK they are provided to all new parents as part of the Personal Child Health Record (PCHR) – known as the "red book". They are used in general practice, community paediatrics, general paediatrics and paediatric endocrinology. The most recent charts are for use in children with growth or nutritional problems.

2. Underpinning research

Until 2009, growth charts used in the UK were based on the British 1990 reference. Following a recommendation by the English Department of Health (DH) Scientific Advisory Committee on Nutrition (SACN), they were replaced by new charts based on the World Health Organization (WHO) 2006 growth standard. These new UK-WHO charts were designed by a Growth Chart Expert Group commissioned through the Royal College of Paediatrics and Child Health (RCPCH), which included Professors Tim Cole and Gary Butler, and Dr Helen Bedford (all UCL Institute of Child Health). The Expert Group was chaired by Professor Charlotte Wright (Glasgow University), who is using her chart development work as a separate REF case study.

The charts for 0 to 4 year olds, launched in May 2009, used WHO growth standard data from two weeks to four years, and reanalysed birth data from the British 1990 reference **[1]**. Further charts extending the age range to 18 years were launched in May 2012, based on the same British 1990 reference as before but to an improved design. In addition more specialised "close monitoring" charts were developed for neonates and infants (NICM) and childhood and puberty (CPCM). They incorporate a series of innovative plotting aids devised by Professor Cole, who was thus responsible for the following features:

- Centiles for birth weight, length and head circumference for 23-42 weeks of gestation constructed using Cole's LMS method **[2, 3]**. For this Cole used the LMS method to update pre-existing birth centiles to augment the WHO growth standard (which lacked preterm data).

- A Body Mass Index (BMI) look-up that converts height centile and weight centile to a BMI centile **[4]**. Here Cole used the strong relation between centiles of weight, height and BMI to predict BMI centile. As a result, knowing centiles of weight and height, BMI centile can be predicted to reasonable accuracy without having to calculate or plot BMI on a centile chart.

- An adult height predictor, a nomogram to convert the child's current height centile (at any age) to a predicted adult height, adjusted for regression to the mean **[5]**. This was joint work with Wright, and a simplified version was included with the growth chart. As well as being popular with parents and children, the height prediction is used in conjunction with the parent height comparator (see below) to detect growth disorders.

- A parent height comparator, a nomogram to compare the child's height centile to the mid-parent height centile adjusted for regression to the mean. Again, in joint work with Wright, it provides a graphical method to calculate an improved version of mid-parent height that, with the height predictor (above), detects disordered growth where the two height estimates

are discordant.

Centiles for height and weight for three phases of puberty were constructed using the LMS method. This was joint work with Butler and Wright, where the five Tanner pubertal stages were rationalised into three pubertal phases, and reference centiles for height and weight were constructed for children in each of the three phases separately. Elements of these centiles were incorporated in the CPCM charts to monitor growth in delayed puberty.

3. References to the research

[1] Wright CM, Williams AF, Elliman D, Bedford H, Birks E, Butler G, et al. Using the new UK-WHO growth charts. BMJ 2010;340:c1140. http://dx.doi.org/10.1136/bmj.c1140

[2] Cole TJ, Williams AF, Wright CM, RCPCH Growth Chart Expert Group. Revised birth centiles for weight, length and head circumference in the UK-WHO growth charts. Ann Hum Biol 2011;38:7-11. http://dx.doi.org/10.3109/03014460.2011.544139

[3] Cole TJ, Wright CM, Williams AF, RCPCH Growth Chart Expert Group. Designing the new UK-WHO growth charts to enhance assessment of growth around birth. Arch Dis Child 2011; http://dx.doi.org/10.1136/adc.2010.205864

[4] Cole TJ. A chart to link child centiles of body mass index, weight and height. Eur J Clin Nutr 2002;56:1194-9. http://dx.doi.org/10.1038/sj.ejcn.1601473

[5] Cole TJ, Wright CM. A chart to predict adult height from a child's current height. Ann Hum Biol 2011;38:662-8. http://dx.doi.org/10.3109/03014460.2011.598189

Peer-reviewed funding

Cole has held four successive MRC programme grants:

- Mathematical methods in the assessment of human growth
  - Oct 1998 – Sep 2003, £381,000
  - Oct 2003 – Sep 2008, £380,000
  - Oct 2008 – Nov 2011, £355,000
- The SITAR method of growth curve analysis for growth assessment in translational medicine and life course epidemiology
  - Apr 2012 – Mar 2015, £79,000.

4. Details of the impact

Since their launch in the UK in 2009, the UK-WHO growth charts developed by Cole and others are now used universally. They were introduced in England in May 2009, in Wales and Scotland in January 2010 and in Northern Ireland in October 2010 **[a]**. The charts are available in two formats: A5 charts that are included in the personal child health record (PCHR) known as the "red book", and A4 professional charts (0-4 years, 2-18 years, NICM). All new mothers receive a copy of the PCHR, **[b]** so that in 2012, for example, the PCHR was distributed to all parents of the 813,000 infants born in the four countries that year. The charts and their interpretation were also discussed in the government's *Birth to Five* book, produced by the Department of Health in 2009 and distributed free to all new parents in England until 2011; in Wales a bilingual edition is issued **[c]**.

The A4 professional charts are used in primary, secondary and tertiary care, and for the year to April 2013 the numbers sold by the publishers, Harlow Printing Limited, for each chart were as

follows:

- 0-4 years – 400,000 copies
- 2-18 years – 287,000 copies
- NICM – 95,000 copies **[d]**

These numbers are impressive, not only in terms of their size, but also because they show how rapidly the UK-WHO charts have superseded the previous British 1990 charts (amounting to 90% of total growth chart sales).

As they enable practitioners to recognise the range of normal development, the UK-WHO charts are uniquely well designed to achieve UK government policy aims in relation to child health, namely with regard to early recognition of growth disorders and risk factors for obesity, as defined in the Healthy Child Programme **[b, e]**. In June 2013, the CPCM chart was released. This is a modification of the main school age chart for use in children with growth or nutritional problems. It extends to age 20 years and features a body mass index (BMI) chart; low and high lines to monitor unusually short, thin or overweight children; puberty phase specific thresholds to assess small children with late onset puberty and tall children with early onset puberty **[f]**.

The UK work has also had an impact internationally. For example, the 0-4 years and NICM charts have been adapted for use in New Zealand **[g],** where they have been used since mid-2010. From January 2013, they have also been in use in Ireland **[h]**, where all newborn infants are assessed using them. As an indication of reach, 72,000 babies were born in Ireland in 2012 **[i]**.

The guiding principles in the chart design were that the charts should be evidence-based, useful and easy to use – and hence more likely to be effective. Parents often claim to understand growth charts, yet they show only limited comprehension when tested **[j]**. Therefore the charts were developed with better layout than before, and with instructions for the PCHR and A4 charts targeted at their respective audiences, parents and professionals **[k]**.

The new and improved elements on the charts also benefit both parents and professionals. These include a reduced emphasis on the 50th centile, as sometimes parents expect all 'normal' children to grow along the 50th centile line. On the new charts however, there are more centile labels and the curve labels sit on the 50th centile to assist orientation when plotting and interpreting **[l]**. A 'dip' in weight between 2-4 weeks is no longer seen, as the charts have more information on weight gain in the first few weeks, and they allow for the average tendency for infants to show a slower net weight gain up to age 2 weeks **[l]**.

The new adult height predictor tells parents how tall their child will be, a matter of endless interest. It also allows professionals to compare the prediction with the parents' heights, and hence detect a possible growth disorder. For this a graphical parent height comparator is provided, which improves on the British 1990 calculator by avoiding the need for any calculations.

Child obesity is a considerable public health concern, and these charts provide better tools for assessing possible weight problems in children. In the past, BMI in children has been relatively little used as a screening tool, due to the need for calculation and a separate BMI chart. The new charts include a BMI look-up, which provides the BMI centile from the height and weight centiles, avoiding both BMI calculation and a BMI chart. This makes it easy to plot the child's BMI centile over time, and it is likely to considerably increase parental and professional awareness of a child's overweight, which parents are poor at recognising **[m]**.

5. Sources to corroborate the impact

[a] Information accompanying the introduction of the new growth charts in England in May 2009: http://www.smahcp.co.uk/professional-know-how/growth-charts/new-growth-charts/information-771.aspx?catid=22
Introduction in Scotland: http://www.scotland.gov.uk/Resource/Doc/337318/0110676.pdf See

p6.

[b] Healthy Child Programme - Pregnancy and the first five years. English Department of Health. http://webarchive.nationalarchives.gov.uk/20130107105354/http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/@dh/@en/@ps/documents/digitalasset/dh_118525.pdf See p 8 for policy aims; p 58 for details of the PCHR.

[c] Birth to Five book, Chapter 4, p. 66, http://www.publichealth.hscni.net/publications/birth-five; Continued use in Wales http://wales.gov.uk/topics/health/improvement/index/earlyyears/?lang=en

[d] Personal communication from Harlow Printing Limited (copy available on request)

[e] Healthy Child Programme – From 5-19 years old. English Department of Health. http://webarchive.nationalarchives.gov.uk/+/www.dh.gov.uk/en/publicationsandstatistics/publications/publicationspolicyandguidance/dh_107566

[f] School age charts and resources, RCPCH, http://www.rcpch.ac.uk/child-health/research-projects/uk-who-growth-charts/uk-growth-chart-resources-2-18-years/school-age

[g] Well Child growth charts. Ministry of Health, New Zealand. http://www.health.govt.nz/our-work/life-stages/child-health/well-child-tamariki-ora-services/growth-charts

[h] UK-WHO-Ireland growth charts. Health Services Executive, Ireland. http://www.hse.ie/growthmonitoring/

[i] Ireland Perinatal Statistics Report 2012: http://www.esri.ie/news_events/latest_press_releases/perinatal-statistics-repo-1/index.xml

[j] Do Parents Understand Growth Charts? A National, Internet-Based Survey; EP Ben-Joseph, SA Dowshen, N Izenberg, Pediatrics 124(4) Oct 2009; pp. 1100 -1109 http://doi.org/10.1542/peds.2008-0797

[k] Sachs M, Sharp L, Bedford H, et al. 'Now I understand': consulting parents on chart design and parental information for the UK-WHO child growth charts. Child Care Health Dev 2012;38:435-40. http://doi.org/10.1111/j.1365-2214.2011.01256.x

[l] The UK-WHO Growth Charts: What is the difference? http://www.rcpch.ac.uk/sites/default/files/asset_library/Research/Growth%20Charts/Education%20Materials%2001092010/FS2_What%20is%20the%20differenceN.pdf

[m] Maternal and Child Awareness and Expectations of Child Overweight; A Brødsgaard, L Wagner, B Peitersen, I Poulsen, T Sørensen; Obesity Facts 2011;4:297–304; http://doi.org/10.1159/000331012