

GROWTH REFERENCE CHARTS FOR USE IN THE UNITED KINGDOM

Recommendations of an expert consensus group

BACKGROUND

The growth charts in general use in this country are currently based on 3 different growth references, while a number of others are used in more specialised settings. There continues to be confusion about the status, validity and comparability of the different references and charts and it was felt that this was an area where paediatricians, as well as others engaged in growth monitoring would appreciate guidance. Our working group, convened by the RCPCH under the auspices of the Standing Committee on Nutrition, met first in October 1999 and again in July 2000. It comprised representatives of the 2 teams involved in constructing the main references as well as others with an expert interest in the subject.

Terminology

All growth charts considered here have been constructed using a growth reference which has been compiled using data from normal healthy children. All growth reference charts currently in use are intended to be descriptive of prevailing growth patterns and are therefore “*references*”, as opposed to prescriptive “*standards*” that define an optimum growth pattern. This document therefore refers throughout to “*Growth references*”. The *Growth Charts* that they are used to construct are simply visual representations of the Growth Reference and can, using modern computer graphics, be re-drawn into almost any format, given the permission of those who own the copyright to the references.

Review Methodology

For each reference included, the group considered the data on which it was based and when they were collected, how the reference was constructed and what peer reviewed or other publications have described it. This aspect, too detailed to be fully covered in this document has been summarised elsewhere in a review (Cameron 2000). The group then considered what is known about each reference’s current validity - the extent to which it accurately represents current growth norms - using a range of published and some unpublished data. Finally the group arrived at conclusions about which reference was to be recommended in any one setting and which references were no longer valid.

Why does the validity of a reference matter and when ?

Charts constructed from growth references are used in two broad clinical settings: the assessment and monitoring of individual children and in screening whole populations. It is in this latter area that discrepancies between a reference and the population it is supposed to describe are most important, because of the large numbers of children involved. However discrepancies may similarly be important for individuals being monitored, if they lead to inappropriate action or inaction.

Two kinds of discrepancies may occur. A cross-sectional discrepancy is present where the proportion below any particular centile is consistently greater or less than expected. This is particularly important in height screening programmes which specify a low centile as a referral threshold. Quite a small variation in the fit can greatly affect the proportion referred.

A longitudinal discrepancy is present where the fit of the growth curve varies with age. While cross sectional charts such as these are not strictly valid for monitoring growth over time, they are widely used for that purpose and it is known that the majority of children track within a band roughly 2 centile spaces (1.5 SD) wide for weight and 1 centile space (0.67 SD) for height. However, if the fit of the reference varies with time it may produce apparent downward centile

crossing in normally growing children and trigger unnecessary concern. This type of discrepancy is of greatest concern for weight monitoring during infancy, but it can also be important in any children monitored over time.

The age when each reference is most used may also be relevant. Height may be measured once pre-school, but in practically all at school entry. Thus the age when the height reference is most used for screening will be 3 - 5 years, although the main clinical use is from ages 5-15. By contrast the most intensive use of the weight and head circumference references is in infancy. Thus the validity of the main references was considered in two broad age ranges: "Infancy" (under 2 years) and childhood (2-18 years), with recommendations made for each.

The discussions at the meeting and the resulting recommendations were confined to references widely used at present or in the past. These were the Tanner and Whitehouse (TW), Gairdner-Pearson (GP), Buckler-Tanner (BT) and UK 1990 (UK90) references for height, weight, head circumference and body mass index.

Main UK Growth References in current or recent use

Reference	Publication	Age commences	Age finishes	Measurements included
Tanner Whitehouse	(Tanner et al. 1966a; Tanner et al. 1966b)	birth	19 yrs	Weight, height, velocity, head > 1year
	(Tanner et al. 1975)	birth	19 yrs	Skin folds
	(Tanner et al. 1976)		19 yrs	Longitudinal references, stages of puberty
Gairdner Pearson	(Gairdner et al. 1971)	28 weeks gestational age Subsequently extended to 24 weeks.	2 yrs	Weight, height, head
Buckler Tanner	(Buckler et al. 1997)	2yr	20 yrs	weight, height, longitudinal references, stages of puberty
UK 1990	(Freeman et al. 1995; Preece et al. 1996)	23 weeks*	20 yrs	weight
		33 weeks*	20 yrs	height, BMI,
		23 weeks*	18 years	head circumference stages of puberty

*gestational age

In addition to the above there are other references in occasional use in the general population. These include various versions of the US growth references (Hammill et al. 1977; Kuczmarski et al. 2000) and what is known as the Sheffield or CONI chart (Carpenter/ Emery, unpublished). A new "Euro-reference" has recently been constructed and is used in some specialist computerised growth programmes (Haschke et al. 2000; Van't Hof et al. 2000). None of these are at present recommended for general use in the United Kingdom.

There are also charts available for specific conditions such as Down's or Turner's syndromes but these were not considered by the group.

FINDINGS

Infancy (under 2 years)

Only the Gairdner Pearson (GP) (which incorporated the original Tanner and Whitehouse infancy reference) and the UK90 references cover the age period from birth to 2. The GP reference goes back to 24 weeks gestation for both weight and height, while the UK90 reference for weight goes back to 23 weeks gestation, but only to 33 weeks for length. While earlier gestations have been added over time the GP has not been otherwise updated since 1975. The UK90 reference is based on larger numbers at all ages, particularly in the pre-term period.

Weight

The Gairdner-Pearson reference has been found to be unreliable in infancy for two reasons. There are major discrepancies in the *shape* of the curve, first described in 1986 (Whitehead et al. 1986) which causes the average contemporary child, compared to either TW or GP, to cross the equivalent of one centile space (2/3 SD) downwards between age 3 and 9 months (Wright et al. 1993; Savage et al. 1996). There are also gender discrepancies which cause the average boy, compared to either TW or GP, to be ½ centile space (1/3 SD) higher than the average girl from age 3-12 months (Wright et al. 1996). Both these discrepancies have also been found in the previous US NCHS reference (Whitehead, Paul et al. 1986; Wright, Waterston et al. 1993; Wright, Corbett et al. 1996). The first published version of the UK90 reference also had a substantial gender discrepancy, but this has since been largely corrected, (Preece, Freeman et al. 1996) and the general fit with contemporary infants is good (Savage et al. 1999).

Length

Length is rarely measured in infancy and not usually in isolation from weight. The limited available validation data suggest that the Gairdner Pearson length reference also shows major discrepancies (Savage, Reilly et al. 1996), while the UK90 length reference shows a fairly good fit (Savage, Reilly et al. 1999).

Head Circumference

The Gairdner- Pearson reference shows striking differences from contemporary infants, who generally have larger heads than the reference. At the extremes this means that the average head size for boys at age 6 months is the 75th percentile (Savage, Reilly et al. 1996). The UK 90 reference shows a much better fit with contemporary infants (Savage, Reilly et al. 1999).

Pre-term infants

The pre-term section of any growth chart can only be validly used to assess centile positions at birth, because it is merely a cross sectional chart of birth weights at each gestation. It cannot be used to assess growth pattern in the first weeks after birth in very pre-term infants (<32 weeks) as few such infants track their original line centile lines. Weight usually drops around two centile spaces in the early weeks. No validation data are available for either reference in pre-term infants, but the UK 90 pre-term data are based on a much larger and more recent data set than the GP. The discrepancies of the GP chart post-term described above also affect pre-term infants as the pre-term section of any growth chart can only be validly used to assess centile position at birth they grow. It was accepted that a pre-term to 2 year format growth chart is helpful to allow neonatologists to track growth after discharge and that this is currently only available for the GP reference.

Conclusions: Infancy

- Recommend that the UK 90 reference for weight, length and head circumference be used for term and pre-term children under 2.
- Advise against the further use of the Gairdner Pearson or Tanner and Whitehouse reference in infancy.
- Advise that a pre-term to 2 year format growth chart should be produced for pre-term infants, based on UK90 data.

CHILDHOOD: AGE 2 UPWARDS

Height

There was agreement that the Tanner & Whitehouse reference (1966) was now obsolete because of the well recognised secular trend towards increasing height at all ages (Rona et al. 1999). The Buckler height reference was adjusted to allow for the secular trend and is therefore very similar to the UK 90. The UK 90 reference (and thus the revised Buckler reference) has been shown to have a high validity when compared to contemporary data (Rudolf et al. 2000).

Height in puberty

Height normally crosses centiles in puberty, because of the variation in age at puberty. This makes cross-sectional references unhelpful for assessing growth in individual children. The Buckler reference incorporates Tanner's allowance for variations in growth rate over puberty while the UK 90 reference does not. However, it has been argued that Tanner's method is only valid for a restricted sub-group of children going through puberty (Preece 1998).

Weight

Most assessment of growth in mid childhood makes little use of the weight component of the growth reference. Despite the increase in height, for which adjustment was made, the Buckler reference was not fully adjusted to allow for secular trends in weight. The UK 90 reference fits contemporary data much better, but it has been suggested that these are already out of date, with a rapid trend to increasing weight particularly in older children and at the top end of the age range (Rudolf, Cole et al. 2000).

Conclusions: Childhood weight and height

- Recommend that either the UK 90 or the Buckler reference is of equivalent robustness for assessing cross sectional height in isolation.
- Advise against further use of the Tanner & Whitehouse reference for either height or weight.
- Recommend that only the UK 90 reference be used where weight is an important component of the assessment.

Weight relative to height

The only available reference for weight adjusted for height in this country is the UK 90 Body Mass Index (BMI) reference, a measure which is widely used internationally in adults, particularly for the assessment of obesity. The UK 90 reference seems to show a reasonable fit, but it appears that a larger than expected proportion of children are above the upper centiles, particularly at later ages (Reilly et al. 1999a; Reilly et al. 1999b; Rudolf, Cole et al. 2000). It has been widely suggested that this reflects a continuing secular trend to an increase in childhood fatness.

Weight-for-height, though a widely used measure internationally, particularly in the assessment of malnutrition, has no UK reference. A US reference does exist but is of unknown validity in British children and only applies to a restricted age range. Calculation of weight-for-height is prone to computation and plotting error.

Conclusions: Weight relative to height

- Recommend that the UK 90 BMI reference be used for assessing weight relative to height
- Advise that weight-for-height should not be used
- Advise that the UK90 BMI reference may not truly represent the prevailing BMI distribution in contemporary children due to a secular trend to increased childhood fatness.

Head circumference

Head circumference is rarely measured outside infancy and if so, usually for specialist monitoring of head growth only. The Tanner-Whitehouse and UK 90 references show striking differences from each other, with the UK90 reference on average 1-2 centile spaces (> 1 SD) higher. The largest discrepancy is at ages 18-20, which would most often be used to assess parental head centiles. The shape of the two curves also differs markedly in puberty. When compared to contemporary children in a limited age range, neither reference shows an acceptable fit, each varying by ± 1 centile space (unpublished data: Charlotte Wright).

Conclusions: Head circumference

- Advise that either TW or UK90 reference could be used with caution for monitoring head growth in individuals prior to puberty, as long as the same reference is used consistently.
- Advise that there is no robust head circumference reference suitable for diagnosing abnormalities of head size in children aged over 2 or for comparing child to parental head centiles or for monitoring head growth in individual children through puberty.

THE FUTURE

This group has concluded that for most clinical purposes the UK90 reference is superior and, in many settings, the only usable reference that can be recommended. To date the UK 90 reference has been warmly adopted in some clinical settings while resisted in others. We are aware that change of any kind is unsettling and disruptive and that if such a change is made it should be to a lasting alternative. Further improvements and refinements are needed in the area of chart design using the UK90 reference, particularly for the assessment of pre-term neonates. However further changes to the data on which the charts are based are undesirable, since they cause confusion among users and preclude comparisons over time. This latter is of great importance in the assessment of the secular trend to increasing weight and BMI. The exception to this would be the head circumference and pre-term length. If new data can be obtained there would be a strong argument for constructing a new, robust head circumference reference from age two into adulthood and there is also a need for more pre-term length data to extend that reference back to earlier gestations.

It is therefore our recommendation that

- The UK 1990 are now the only suitable reference charts for use in children under 2 and in older children where both weight and height are being evaluated.

- The current UK90 references for weight, height and BMI should now be kept unchanged for the foreseeable future (10 –20 years), both to avoid confusion and to allow a base for comparison for weight and BMI trends.
- The RCPCH should take on the role of monitoring and advising on the validity of growth references in use in this country as well as identifying areas in need of further research and development.
- Future revisions of the UK90 references should be carefully planned and introduced only with RCPCH support and after wide-ranging consultation.

COMPOSITION OF THE GROUP:

The following attended at least one of the two meetings, have seen the final draft and have fully agreed to its recommendations:

Prof Ian Booth	Chairman of RCPCH standing Nutrition committee; Institute of Child Health, Birmingham
Dr John Buckler	University of Leeds
Prof Noel Cameron	University of Loughborough
Prof Tim Cole	Institute of Child Health, London
Prof Michael Healy	Emeritus Professor, LSHTM
Dr Tony Hulse	British Association Paediatric Endocrinology and Metabolism
Prof Michael Preece	Institute of Child Health, London
Dr John Reilly	University of Glasgow
Dr Anthony Williams	St George's Medical School, London
Dr Charlotte Wright	University of Newcastle upon Tyne

REFERENCES

- Buckler, J and Tanner, J (1997). "Revision and update of Tanner - Whitehouse clinical longitudinal charts for height and weight." *European Journal of Paediatrics* **156**(letter): 248-9.
- Cameron, N (2000). "A review of British Growth Charts for height and weight with recommendations concerning their use in general paediatric practice." *In Preparation*.
- Freeman, JV, Cole, TJ, Chinn, S, Jones, PRM, White, EM and Preece, MA (1995). "Cross sectional stature and weight reference curves for the UK, 1990." *Arch Dis Child* **73**: 17-24.
- Gairdner, D and Pearson, J (1971). "A growth chart for premature and other infants." *Arch Dis Child* **46**: 783-787.
- Hammill, PVV, Johnson, CL, Reed, R and al, e (1977). NCHS growth curves for children birth - 18 years., National Centre for Health Statistics.
- Haschke, F, van't Hof, M and Group, E-GS (2000). "Euro-Growth References for length, weight, and body circumferences." *J Pediatr Gastroenterol Nutr* **31**(suppl 1): S14-38.
- Kuczmarski, R, Ogden, C, Grummer-Strawn, L, Flegal, K, Guo, S, Wei, R and al, e (2000). CDC Growth charts: United states. Hyattsville, Maryland, USA, National centre for Health Statistics.
- Preece, M, Freeman, J and Cole, T (1996). "Sex differences in weight in infancy: published centile charts have been updated." *BMJ* **313**: 1486.
- Preece, M (1998). Cross-sectional versus longitudinal growth references. *Proceedings of the Annual Spring Meeting*. York, Royal College of Paediatrics and Child Health. **2**: 31.
- Reilly, J and Dorosty, A (1999a). "Epidemic of obesity in UK children." *Lancet* **354**: 1874-1875.
- Reilly, J, Dorosty, A and Emmett, P (1999b). "Prevalence of overweight and obesity in British children: cohort study." *BMJ* **319**: 1039.
- Rona, R and Chinn, S (1999). *The national study of health and growth*. Oxford, Oxford University Press.
- Rudolf, M, Cole, T, Krom, A, Sahota, P and Walker, J (2000). "Growth of primary school children: a validation of the 1990 references and their use in growth monitoring." *Arch Dis Child* **83**(4): 298-301.

- Savage, S, Reilly, J and Durnin, J (1996). "Weight and length of Glasgow infants compared to Tanner and Whitehouse standards and new British standards for growth." *Proceedings of the Nutrition Society* **55**: 81A.
- Savage, S, Reilly, J, Edwards, C and Durnin, V (1999). "Adequacy of standards for assessment of growth and nutritional status in infancy and early childhood." *Archives of Disease in Childhood* **80**: 121-4.
- Tanner, J, Whitehouse, R and Takaishi, M (1966a). "Standards from birth to maturity for height weight height velocity and weight velocity: British children 1965 Part I." *Arch Dis Child* **41**: 454-471.
- Tanner, J, Whitehouse, R and Takaishi, M (1966b). "Standards from birth to maturity for height weight height velocity and weight velocity: British children 1965 Part II." *Arch Dis Child* **41**: 613-35.
- Tanner, J and Whitehouse, R (1975). "Revised standards for triceps and subscapular skin folds in British children." *Archives of Disease in Childhood* **50**: 142-5.
- Tanner, J and Whitehouse, R (1976). "Clinical longitudinal standards for height, weight, height velocity and weight velocity and stages of puberty." *Archives of Disease in Childhood* **51**: 170-179.
- Van't Hof, M, Haschke, F and Group, E-GS (2000). "Euro-Growth References for body mass index (BMI) and weight for length (WfL)." *J Pediatr Gastroenterol Nutr* **31 (suppl 1)**: S48-59.
- Whitehead, R, Paul, A and Ahmed, E (1986). "Weaning practices in the United Kingdom and variations in anthropometric development." *Acta Paediatr Scand* **323**(Suppl): 14-23.
- Wright, CM, Waterston, A and Aynsley-Green, A (1993). "A comparison of the use of Tanner, NCHS and Cambridge weight standards in Infancy." *Arch Dis Child* **69**: 420-22.
- Wright, C, Corbett, S and Drewett, R (1996). "Sex differences in weight in infancy and the British 1990 growth standards." *BMJ* **313**: 513-4.