ORIGINAL ARTICLE

Growth reference charts for use in the United Kingdom

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Since the introduction of new growth charts in the mid 1990s, there has been confusion about which charts should be used, with many districts using more than one version. Because of this uncertainty, an expert working party, the Growth Reference Review Group, was convened by the Royal College of Paediatrics and Child Health to provide guidance on the validity and comparability of the different charts currently in use. This paper describes the technical background to the construction and evaluation of growth charts and outlines the group's findings on the validity of each growth reference in relation to contemporary British children. The group concluded that for most clinical purposes the UK90 reference is superior and for many measures is the only usable reference that can be recommended, while the original Tanner–Whitehouse and the Gairdner–Pearson charts are no longer reliable for use at any age. After the age of 2 the revised Buckler–Tanner references are still suitable for assessing height. There are presently no reliable head circumference reference charts for use beyond infancy. The group propose that apart from refinements of chart design and layout, the new UK90 reference should now be "frozen", with any future revisions only undertaken after careful planning and widespread consultation

The growth charts in general use in the UK are currently based on three different growth references and 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. A working group was therefore convened by the Royal College of Paediatrics and Child Health (RCPCH) which comprised representatives of the two teams involved in constructing the main references, as well as others with an expert interest in the subject. Members were unanimous in their recommendations, which have also been ratified by the RCPCH Standing Committee on Nutrition and its Executive Council.

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 references currently in use are intended to be descriptive of prevailing growth patterns and are therefore "references" and not prescriptive "standards" that define an optimum growth pattern. The growth charts constructed from these data are simply visual representations of the growth reference and can, using modern computer graphics, be redrawn into almost any format, given the permission of those who own the copyright to the data. Most growth charts are expressed in centiles lines rather than SD scores, but the exact centiles used vary. However both the original Tanner and Whitehouse charts and the newer UK 1990 reference used similarly spaced centile lines, so that one centile space (the distance between two centile lines) is close to 2/3 SD.

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 also 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 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 two centile spaces (1.3 SD) wide for weight and one 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 in the preschool years, but in practically all children 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. In contrast the most intensive use of the weight and head circumference references is in infancy.

REVIEW METHODOLOGY

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

Abbreviations: BMI, body mass index; BT, Buckler–Tanner; GP, Gairdner–Pearson; RCPCH, Royal College of Paediatrics and Child Health; TW, Tanner–Whitehouse

Table 1 Main UK growth references in current or recent use

Reference	Charts published by	Peer reviewed publication date	Age commences	Age finishes	Measurements included
Tanner–Whitehouse	Castlemead Publications	1966[18 19]	Birth	19 y	Weight, height, velocity, head (>1 year)
		1975[20]	Birth	19 y	Skin folds
		1975[21]		19 y	Longitudinal references, stages of puberty
Gairdner–Pearson	Castlemead Publications	1971[22]	28 wk*	2 y	Weight, height, head
Buckler–Tanner	Castlemead Publications	1997[23]	2 y	20 y	Weight, height, longitudinal references, stages of puberty
UK 1990	Child Growth Foundation	1995, 1996[10 24]	23 wk	20 y	Weight height, BMI, head circumference, stages of puberty
			33 wk	20 y	
			23 wk	18 y	

*Subsequently extended to 24 weeks gestational age.

body mass index (BMI). Other references used only occasionally in the general UK population (the US growth references,[1 2] the "Sheffield" or "CONI" chart (Carpenter/Emery, unpublished) and a new "Euro-reference"[3 4]) were not considered by the group. Similarly, references for specific conditions, such as Down's or Turner's syndromes, were not included in the review.

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[5] (table 1). 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) growth data from studies of representative British children, not used as a data sources for any of the growth references. Finally, the group arrived at conclusions about which reference was to be recommended in any one setting and which references were no longer valid. The main references were considered in two broad age ranges: infancy (under 2 years) and childhood (2–18 years).

INFANCY

Only the GP (which incorporated the original Tanner and Whitehouse infancy reference) and the UK90 references cover the ages from birth to 2 years. The GP has not been updated since 1975, apart from the addition of earlier gestations. The UK90 reference is both more recent and based on larger numbers at all ages.

The GP *weight* 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,[6] which cause the average contemporary child, compared to either TW or GP, to cross the equivalent of one centile space (0.67 SD) downwards between ages of 3 and 9 months.[7 8] There are also gender discrepancies, which cause the average boy, compared to either TW or GP, to be 0.5 centile space (0.33 SD) higher than the average girl from age 3–12 months.[9] Both these discrepancies can also be seen in the US NCHS reference.[6 7 9] The first published version of the UK90 reference also had a substantial gender discrepancy, but this has since been largely corrected,[10] and the general fit with contemporary infants is good.[11]

Length is infrequently measured in infancy and not usually in isolation from weight. However, the limited available validation data suggest that the GP length reference also shows major discrepancies from the growth of contemporary children,[8] while the UK90 length reference shows a fairly good fit.[11]

The GP *head circumference* 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 centile.[8] The UK90 reference shows a much better fit with contemporary infants.[11]

The *preterm* section of any growth chart can only be validly used to assess centile position 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 preterm infants (<32 weeks). This is because few such infants track their original centile lines, with their weight usually dropping around two (UK90) centile spaces in the early weeks. No validation data are available for either reference in preterm infants, but the UK90 references are based on a much larger preterm data set than the GP.

The discrepancies of the GP chart post-term, described above, also affect preterm infants as they grow. It was accepted that a preterm 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. It is hoped that a preterm to 2 year format growth chart based on UK90 data could soon be produced.

CHILDHOOD

There was agreement that the TW height reference (1966) was now obsolete because of the well recognised secular trend towards increasing height at all ages.[12] The Buckler height reference was adjusted to allow for the secular trend and is therefore very similar to the UK90. The UK90 reference (and thus the revised Buckler reference) has been shown to have a high validity when compared to contemporary data.[13]

In *puberty* height normally crosses centiles, because of the variation in age at onset. 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 UK90 reference does not. However, it has been argued that Tanner's method is only valid for a restricted subgroup of children going through puberty.[14]

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 UK90 weight reference fits contemporary data better, but it has been suggested that this is already out of date as a description of current norms, with a rapid trend to increasing weight, particularly in older children and at the top end of the age range.[13]

The only available reference for *weight adjusted for height* in this country is the UK90 BMI reference, a measure which is widely used internationally in adults, particularly for the assessment of obesity. The UK90 reference seems to show a reasonable fit, but a larger than expected proportion of children are currently above the upper centiles, particularly at later ages.[13 15 16] It has been widely suggested that this reflects a continuing secular trend to an increase in childhood fatness.

Percentage weight for height, though a widely used measure internationally, particularly in the assessment of malnutrition, has no UK reference. A US reference does exist,

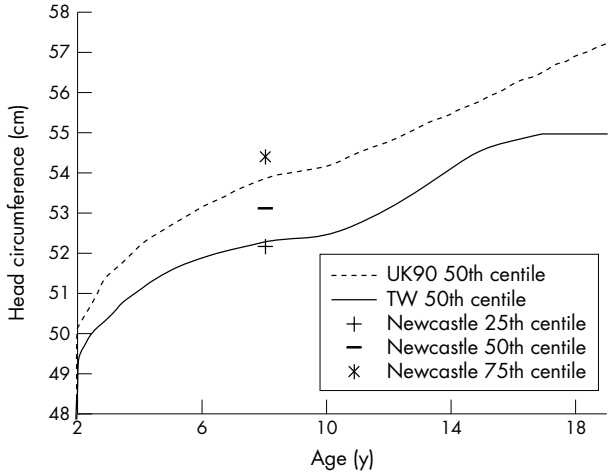

Figure 1 Tanner and Whitehouse and UK90 head circumference 50th centiles (male data only shown) compared to survey data from Newcastle (221 boys, 20% systematic sample from complete birth cohort, born 1987–88, aged 8.5 years[25]).

but is of unknown validity in British children and only applies to a restricted age range. Calculation of percentage weight for height is also prone to computation and plotting error.[17]

Head circumference is rarely measured beyond infancy, and then usually for specialist monitoring of head growth only. The TW and UK90 references show striking differences from each other in this age range, 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 notably 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; see fig 1). This means that neither reference is robust for diagnosing abnormalities of head size after the age of 2 years or for monitoring head growth after the onset of puberty.

THE FUTURE

This group has concluded that for most clinical purposes the UK90 reference is superior, and for many measures is the only usable reference that can be recommended. To date the UK90 reference has been readily adopted in some clinical settings but resisted in others. Change of any kind is unsettling and disruptive, but it is important that familiarity with a clinical tool does not blind one to its deficiencies. However, if units are to adopt new charts, it is important that these are a lasting alternative. Thus further changes to the data on which the charts are based are undesirable. Updating of references also precludes comparisons over time, which is of great importance in the assessment of the secular trend to increasing weight and BMI. It is therefore hoped that the current UK90 references for weight, height, and BMI will now be kept unchanged for the foreseeable future, with future revisions introduced only after wide ranging consultation.

This freezing of the underlying UK90 reference does not preclude refinements of chart design, particularly for the assessment of preterm neonates. Nor should it preclude changes in the particular areas of weakness noted above (head circumference and the preterm length) if new data become available. The RCPCH hopes, through the Growth Reference Review Group, to continue to advise on the use of growth references in this country, possibly extending this review process to the less commonly used or more specialised growth references, as well as identifying areas in need of further research and development.

Main recommendations of review group

- The original Tanner–Whitehouse and the Gairdner–Pearson growth references for weight and height/length, are now obsolete and are no longer reliable for use at any age

Under the age of 2

- The UK90 are the only suitable reference charts for weight, length, and head circumference

After the age of 2

- Both the UK90 and the Buckler references are suitable for assessing cross sectional height in isolation, but the UK90 should be used where both weight and height are being evaluated
- The UK90 BMI reference is the only suitable reference for assessing weight relative to height
- Neither the Tanner–Whitehouse nor the UK90 head circumference reference is robust, but can be used for monitoring head growth prior to puberty with caution, as long as the same reference is used consistently

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A longer version of this paper is available on the RCPCH website at www.rcpch.ac.uk

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ARCHIVIST

Cervical spine injuries

Only 1% or 2% of children admitted to hospital after trauma have cervical spine injuries but the consequences can be enormous. Records from the Children's Hospital in Cincinnati, Ohio have been analysed (Rebeccah L Brown and colleagues. *Journal of Pediatric Surgery* 2001;**36**:1107–14).

Over a period of 9½ years (1991–2000) 103 children were admitted with cervical spine injuries. The peak age of injury was 14 years. Over half of the injuries (52%) were sustained in traffic accidents and, in these, 59% of the victims were passengers. Other mechanisms of injury included sports injuries (27%), falls (15%), and child abuse (3%). Most injuries (68%) were high cervical (C1 to C4). Thirty-eight per cent of the children had spinal cord injury without radiographic abnormality (SCIWORA—another one for AAC (Archivist's Acronym Collection)). Head injuries also occurred in 38% of patients. Nineteen children died, of whom 18 had been injured in a motor vehicle accident (the other death was from child abuse). The risk of death was greatest in younger children, those with upper cervical spine injuries, and those with associated head injury. Three quarters of the children with sports injuries and all of those suffering from child abuse had SCIWORA.

In younger children motor accidents were the predominant cause and sports injuries affected mainly older boys. Cervical spine fractures most commonly resulted from falls or dives, cervical spine dislocations from motor vehicle related trauma (especially to pedestrians), and SCIWORA from sports injuries and child abuse. Five patients had complete spinal cord lesions, all of them with low (C4–C7) lesions. Four of these had motor vehicle related injuries and all four died.

Cervical spine injuries in children are uncommon but potentially disastrous. Cord injury may occur without radiographic abnormality, especially with sports injuries or child abuse.