CURRENT TOPIC

Growth monitoring

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Normal growth is a sign of good health and ill children often grow slowly, so growth must be assessed in any child presenting with, or monitored for, important health problems, whether in specialist or primary care practice. But what are the benefits of routine growth monitoring in apparently well children? The value of growth monitoring in developing countries has recently been questioned,[1] but no systematic review has been published of growth monitoring in the industrialised world, and little guidance is available from formal trials. A multiprofessional group (see acknowledgements at end of paper) met in Coventry in 1998 to develop a consensus and agreed that the potential benefits of growth monitoring include: identification of chronic disorders; provision of reassurance to parents; monitoring the health of the nation's children; and supporting future research. This article aims to summarise the issues with regard to children over 2 years of age—growth monitoring in the under 2 year olds has been reviewed elsewhere.[2]

In some conditions (table 1), the child is abnormally short or tall from infancy onwards, whereas in others initial normal growth is followed by growth failure or acceleration. Individual measurements at a single point in time detect absolute short or tall stature but two or more measurements over a period of time are needed to detect a change in growth rate, irrespective of the starting height—hence the preferred term is "growth monitoring", not "screening". Nevertheless, growth monitoring is a form of screening—it involves offering a simple rapid test to apparently healthy people, to separate a group of subjects who are at high risk of having abnormal growth from a larger group who are at low risk. The classic requirements for screening programmes are well known (table 2). How well does growth monitoring perform?

Table 1 The main conditions affecting growth

Short stature or growth failure
Isolated growth hormone deficiency
Multiple pituitary hormone deficiency
Turner's syndrome
Psychosocial deprivation
Silver-Russell syndrome
Skeletal dysplasias and bone disorders
Noonan's syndrome
Neurofibromatosis
Hypothyroidism
Inflammatory bowel disease
Coeliac disease
Chronic renal disease
Tall stature or accelerated growth
Marfan's syndrome
Klinefelter's syndrome (XXY)
XYY syndrome
Sotos' syndrome
Thyrotoxicosis
Congenital adrenal hyperplasia
Premature sexual maturation
Pituitary gigantism

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The target conditions

Growth monitoring would be most useful in identifying conditions that meet two criteria: no other clinically obvious pointers that might alert parents and primary care staff, and growth patterns that deviate substantially from normal in most cases of the condition. Few of the conditions causing short stature, and none of those causing tall stature, meet these criteria (table 1). Identification of most disorders in the table by growth monitoring should be regarded as secondary gain, not as the primary aim and, if screening for them were thought to be important, growth monitoring would not be the method of choice. Short stature with few other clues to a growth disorder occurs mainly in growth hormone deficiency (GHD) and Turner's syndrome. These conditions could be identified by, and are the primary justification for, growth monitoring.[3]

GROWTH HORMONE DEFICIENCY

GHD can occur as an isolated condition, as part of multiple pituitary hormone deficiency, or as a consequence of other disease, usually detected by specialist follow up. Multiple pituitary hormone deficiency usually presents within the first 2 years of life with hypoglycaemia, micropenis, obesity, or obvious failure to thrive, which necessitate investigation.[4] Isolated GHD is often associated with relative obesity and a facial structure typical of younger children, but these are subtle features, and short stature is the most obvious clue. Some children are extremely short, well below the 0.4th centile, at the time of starting treatment,[5] but others are barely outside the normal height range and are much more difficult to identify. Treatment with growth hormone is effective and delay in starting this leads to a reduction in adult height.[6]

TURNER'S SYNDROME

Some girls with Turner's syndrome can be detected antenatally or in the neonatal period,[7] but the remainder, perhaps 60%, are identified

Table 2 How growth monitoring performs against the criteria for a screening programme (based on Wilson and Jungner, with modifications proposed by UK national screening committee 1998)

The condition	
(1)	Should be an important health problem*
(2)	Epidemiology and natural history of the condition should be adequately understood and there should be a detectable risk factor, disease marker, latent period, or early symptomatic stage (Y)
(3)	All cost effective primary prevention interventions should have been implemented (NA)
The test	
(4)	A simple, safe, precise and validated screening test*
(5)	Distribution of the test values should be known and a suitable cut off level agreed*
(6)	The test should be acceptable to the population (Y)
(7)	Agreed policy on further diagnostic investigation of positive test results*
Treatment	
(8)	Effective treatment or intervention; early treatment leading to better outcomes than late treatment (Y)
(9)	Evidence based policies on who should be offered treatment and the appropriate treatment (Y)
(10)	Clinical management of the condition optimised before introduction of screening (N)
The screening programme	
(11)	Evidence that the screening programme is effective in reducing mortality and morbidity (N)
(12)	Complete screening programme (test, diagnostic procedures, treatment/intervention) must be clinically, socially, and ethically acceptable to health professionals and the public (U)
(13)	Benefit should outweigh physical and psychological harm (U)
(14)	Opportunity cost should be economically balanced in relation to expenditure on medical care as a whole (U)
(15)	A plan for managing and monitoring the screening programme and agreed quality assurance standards (N)
(16)	Adequate staffing and facilities for testing, diagnostic treatment, and programme management (U)

First annual report of the National Screening Committee. London: HMSO, 1998.
*Discussed in text.
Y, yes; N, no; U, unknown; NA, not applicable.

because of short stature, amennorhoea, or infertility. Although absolute height and rate of gain in height are both less than in normal girls, there is considerable overlap with the normal range (fig 1).[8 9] Women with Turner's syndrome are 13–19 cm shorter than the average, but the difference is less noticeable in childhood because much of the height deficit arises from failure of the pubertal growth spurt.[10] Figure 1 shows that up to 50% of previously undiagnosed girls with Turner's syndrome could, in theory, be diagnosed on the basis of a height measurement below the 0.4th centile at age 5 years, and two thirds would be below the 2nd centile. The results of a growth study in Utah support this estimate.[11]

The benefits for final height of early treatment with oestrogens and growth hormone are still controversial.[12 13] However, short stature might be less distressing than the infertility, and it may be psychologically better for the girl to grow up knowing about this, rather than discovering it at puberty.

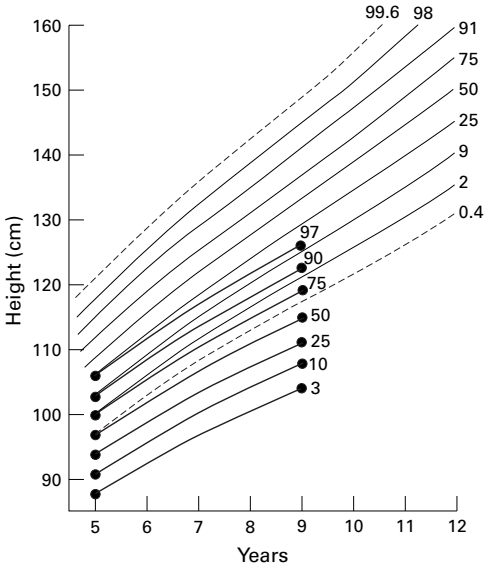

Figure 1 Growth curves for girls with Turner's syndrome superimposed on the 1990 nine centile height chart.

NORMAL SHORT CHILDREN

These children would also be identified by growth monitoring and could be "reassured" about their short stature, or offered treatment. However, psychological distress associated with being short does not seem to be a major problem,[14–16] and growth hormone treatment is of doubtful value for such children.[17]

The tests

Effective growth monitoring needs precise measurement, accurate plotting on appropriate charts, correct interpretation, and a plan of investigation for screen positive cases. Some endocrinologists prefer longitudinal charts,[18 19] but the 1990 nine centile charts are recommended for general use[20 21]—they are well documented, are based on a large dataset, and show not only ± 2 SD lines but also ± 2.67 SD lines; only one child in 250 falls outside these limits. Separate charts for each ethnic group have been considered,[22] but are neither practical nor desirable.

ERROR AND IMPRECISION

Measuring height is subject to error as a result of poor technique, variations between instruments and observers, diurnal variation, and plotting mistakes.[23–26] Stretching the child while measuring will not eliminate diurnal variation, but might increase interobserver error.[26] A degree of imprecision is inevitable, because over 90% of the variation between height measurements is the result of the fact that children are not rigid objects and do not have an exact or correct height.[25] Nevertheless, with training and care, single height measurements can be obtained in community practice with acceptable precision, especially over the age of 3 years (appendix).[27 28]

SINGLE HEIGHT MEASUREMENTS

The most simple approach is to treat each measurement as a single screening test, using the 0.4th centile as a cut off point for short stature. The shorter the child, the greater the probability of organic disease.[29] At any age, a

height measurement under the 0.4th centile, without previous explanation, would merit evaluation. In a cohort of 100 000 children, there might be up to 30 children with isolated GHD[11] and perhaps 12 with Turner's syndrome who had not been diagnosed in the neonatal period. The yield of screening would be less than this, because some children would present clinically as a result of parental concern and some would be above the 0.4th centile in height. Although the yield would increase by using the 2nd centile as the cut off point, the price would be a fivefold increase (from 400 to 2000/100 000) in children needing evaluation. A small number of other previously unrecognised conditions in addition to GHD and Turner's syndrome would be identified by screening.

The school health service is changing rapidly, but in many districts school entry (4–5 years) probably still offers the best single opportunity to identify previously undetected cases of GHD and Turner's syndrome, because almost 100% of children can be examined. The yield would be lower in younger children, because measurement is less precise and the degree of growth failure would be less. A second measurement a year or more after starting school, using the 0.4th centile cut off point, might identify a few of the children missed at age 5, but the yield would inevitably be very small.

Criterion 7 (table 2) indicates the need for an agreed approach to investigation for "screen positive" individuals. Evaluation for most conditions listed in table 1 can be achieved by physical examination and straightforward low cost investigations, within the scope of a general or community paediatrician or an interested general practitioner.[29] Unfortunately, for isolated GHD, the most important target disorder, there is no simple protocol defining how this diagnosis can best be excluded by the non-specialist, or when the expertise of a paediatric endocrinologist should be enlisted.

CORRECTING FOR PARENTAL HEIGHT

Sensitivity of height measurement as a screening test could be improved by including children above the 0.4th centile who are short for parental height. Similarly, specificity could be increased by excluding children below the 0.4th centile whose parents are short. In practice, however, there are a number of difficulties. The height of both parents is not always available, although the height of one parent (or even a sibling) can be useful. Self reported heights and estimated heights of partners are not very reliable. Very short parents might themselves have a growth disorder. One small study found that 4% of normal height children and 40% of short/normal children were outside the expected range when corrected for parental height, whereas half of new cases with pathology were within the expected range (Mulligan J, Voss L, personal communication, 1999).

A new screening chart (TJ Cole 1999, unpublished data) would screen in all children below the 0.4th centile and also those above the population 0.4th centile but below the 0.4th centile adjusted for parental or sibling height. This could improve sensitivity without significantly reducing specificity. Adjustment for regression to the mean can be included.[30] These proposals have not yet been field tested and, at present, correction for parental height is still too complex a procedure for screening.

GROWTH VELOCITY

A single height measurement will identify only those very short (or tall) children whose growth is so deviant that their height centile is outside the cut off point chosen. Children growing slowly because of GHD, Turner's syndrome, or acquired disorders, such as coeliac disease or hypothyroidism, might still be above the cut off centile, particularly if they have tall parents. The occasional late referral of a child whose growth trajectory has (in retrospect) been crossing centiles over several years prompts the question: could poor growth, as opposed to absolute short stature, be detected by growth monitoring? The difficulty is that growth velocity and the change in height standard deviation score[18 31] are calculated from the difference between two height measurements, thereby combining the imprecision of the two readings (appendix).[32] Therefore, single estimates of velocity are not useful. Every child is likely, sooner or later, to show a period of apparently poor growth, which could result in referral.[33] Furthermore, it is not possible to define a "normal" velocity—the rate of growth is conditional on height.[34]

Various operational definitions of "abnormal growth velocity" have been proposed—for example, that for school age children a change of more than plus or minus one centile band (0.67 SD) on the 1990 chart should be considered abnormal. What sensitivity and specificity would this guideline have? Figure 1 illustrates that between 5 and 8 years of age, sensitivity for Turner's syndrome is low—most girls who were missed by the 0.4th centile criterion at age 5 would not shift centiles by this amount. Around one sixth of patients with Turner's syndrome and one third of patients with GHD with height above −2.5 SD (close to the UK 0.4th centile) might be identified by measuring three year height gain between 5 and 12 years of age.[35] Specificity is also a problem—in one community study, 2% of all children crossed one centile band downwards between 5 and 8 years of age[23] (and 2% crossed one band upwards). For infants and preschool children, the measurement error is greater, and both sensitivity and specificity are worse.[35]

Growth monitoring might be more useful if multiple height measures, rather than just two, were to be obtained by primary health care staff, making it easier to identify errors of measuring and plotting and to recognise the truly abnormal pattern. Measuring could be started at age 2 or 3,[27] but the imprecision is greater in younger children and growth failure would be less obvious. Further measurements after starting school would improve precision,

and the error as a proportion of the total increase in height would be less, but interpretation of growth data and diagnosis of growth failure would be more difficult because some normal children show a pronounced but transient faltering in growth before the pubertal growth spurt. Even with several measurements, a formal growth monitoring programme between the ages of 5 and 12 years would have only a modest impact on the age of diagnosis of cases not apparent at age 5,[35] and a high price would be paid in unnecessary referrals and investigations.[36]

One important practical implication of this analysis is that, once obvious pathology has been excluded, there is little logic in a school nurse monitoring height after school entry just for children considered "short" at age 5, because acquired pathology could affect a child of any size.[34]

HOW USEFUL IS WEIGHT?

Weight and height are traditionally assessed together and can be interpreted using a body mass index (BMI) chart.[37] Although the distribution of weights and BMIs corresponds reasonably closely to the 1990 charts at age 5, by age 12 the BMI distribution has changed significantly compared with the 1990 data, indicating a trend to increasing obesity over a very short timescale.[38] The issue is undoubtedly important, but it is not clear what can be done to reverse this trend or tackle the problem at an individual level. The role of BMI charts in community practice needs further study,[39] and "screening" for obesity would not currently fulfil accepted criteria. Recording height and weight together would have greater clinical and public health value than height alone.

Public health aspects

There are two considerations. First, both population trends in height and changes over time in the height differential between social classes are useful health and social indicators.[40] Second, monitoring the changing weights and BMIs of the nation's children is important in view of the high and increasing prevalence of obesity, and could be facilitated by a policy of universal measurement when children start school.

Conclusions

- Single height measurements, with a cut off point at the 0.4th centile on the 1990 charts, come closest to satisfying the criteria for screening.
- School entry offers a good opportunity to screen the whole population. The theoretical advantages are low marginal cost when combined with other school entry screening procedures, potentially high coverage, an acceptable yield of new cases of isolated GHD and Turner's syndrome, secondary benefits in case finding for other disorders, and (when combined with weight) a contribution to a core dataset for child public health.
- Correction for parental height should not at present be undertaken as part of screening.
- Because the school entry measurement offers the best opportunity to identify growth disorders, the measurement must be done to a high standard, so reliable equipment must be supplied and correctly assembled or installed, and staff training is essential.
- Quality and in particular measurement error must be monitored.
- Lack of a validated protocol for the management of children below the 0.4th centile is an important obstacle to an effective screening programme.
- Children whose height is above the 99.6th centile need be referred only if there are other unexplained symptoms or signs.
- Height measurement at other ages, using the 0.4th centile to trigger action, is good clinical practice. It should be undertaken on an opportunistic basis when a child is seen for other reasons, whether in primary or secondary care, but should not be regarded as a total population screening programme.
- Routine growth monitoring to detect centile crossing has too low a sensitivity and specificity to be regarded as screening.

These conclusions will seem counterintuitive to many health professionals, but are supported by empirical and theoretical evidence. The next step is to determine whether it is possible to maintain staffing and standards for the school entry height screen, given the far reaching changes in school health services. Alternatively, the task might be incorporated into primary care—for example, the child could be measured and weighed at the same time as the preschool booster immunisation. Either way, it will be important to improve training for primary care staff in responding to parental concerns about growth and being aware of unusual paediatric disorders.

This paper is based on the "Coventry consensus" meeting attended by some 40 paediatricians, endocrinologists, public health professionals, general practitioners, and nurses in July 1998. The meeting was arranged by the Child Growth Foundation and supported by Cow and Gate, Ferring, Novo Nordisk, Pharmacia, and Serono. I am grateful to all those who contributed to the debate and to successive revisions of the consensus document, which is available (including an expanded version of the table of conditions, notes on measurement, and an extended bibliography) for download and discussion at the following website URL: www.pier.sheff.ac.uk

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Appendix

The best measurement of the precision of height measurement is the standard deviation of a single height measurement (SDshm) which, for school age children, has a value around 0.2–0.3 cm. The 95% confidence interval for a child's height therefore extends about 0.5 cm (2 SDshm) on either side of the measured height so that, if a child's height is observed to be on the 3rd centile we can be very confident that the true height lies between the 2nd and the 4th centile.

The interval width is similar for 3 year olds, but for 2 year olds it is double in size. So the 95% confidence limits of a 2 year old boy's height, measured at 79 cm, would be 78 cm (that is, on the 0.2 centile) and 80 cm (on the 1.2 centile).

The 95% confidence limits to a single height velocity, measured over a full year by the same measurer on both

occasions, lie +2(SDshm)$\sqrt{2}$ cm/year about the measured velocity. For school age children, this works out at +0.71 cm/year. Consequently, a child whose measured velocity over the period 5 to 6 years falls on the 25th centile might have a true velocity between the 8th (worryingly slow) and the 50th (very satisfactory). These confidence limits would have to be doubled if two measurements were taken only six months apart.

These calculations relate only to children randomly chosen from the population. For such children, the correlation between annual height measurements increases with age, so that preschool children are more likely than schoolage children to cross centile bands. Centile crossing is also more likely with longer measurement intervals. If a child is measured a second time only because the first measurement gave cause for concern (for instance because the child was considered unusually short), any inference about that child's growth should take into account that the expected velocity is not the same for every child, but is conditional on the initial height.

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Standardised technique for height measurement

Reliable growth data does not require expensive equipment, just some care. If universally adopted, a standardised technique would increase precision and minimise interobserver bias. The method described here is evidence-based and was debated and accepted at Coventry. The degree of accuracy and precision required depends, ultimately, on how the data are to be used. There are two key questions to keep in mind: *Is the reading accurate?* The accuracy of the measurement depends on the correct installation and regular maintenance of the instruments used. *Is the reading reproducible?* The validity and thus the interpretation of growth data depends on the reproducibility or precision of the measurements. It is crucial to know whether the size of any increment observed over time is likely to be real and not owing to measurement error.

COMMON SOURCES OF ERROR

Careless technique

Most errors arise from the careless reading and recording of data. They will not be obvious unless very large.

Diurnal variation

Height is greatest on getting up in the morning—up to 2.0 cm can be lost over the whole day. Measurements made at different times of day can significantly affect the measured height and, thus, the estimated rate of growth. Subsequent measurements should be made at the same time of day, or at least in the afternoon, when the rate of height loss slows down. NB—Stretching is ineffective in preventing diurnal variation.

Observer differences
Different observers, even apparently using the same technique, may record significantly different heights for a child. Ideally, a child should be monitored by the same observer using the same instrument, but this is not always feasible. An unstretched technique is therefore recommended, as it gives the same degree of intraobserver precision as a stretched method, but minimises interobserver bias resulting from different degrees of stretching.

Non-blind measurement
Where the previous height of the child is known, a further source of bias may be introduced. Measurements should be "blind". Observers should not look at previous data and should not keep measuring until they get the reading they expect to see.

INSTALLATION OF HEIGHT MEASURING EQUIPMENT
Ideally, use a self calibrating stadiometer. It should be placed on a hard, uncarpeted surface, against a bare wall. Wall mounted instruments, if used, must be hung from a permanently fixed nail, not plastic putty. The accuracy of all instruments should be checked with a calibrated rule both before and after each session. Worn instruments should be replaced.

MEASUREMENT TECHNIQUE FOR STANDING HEIGHT
- Check instrument with calibrated rule
- Measure children, ideally, in vest and pants. In all cases, remove shoes, socks, bulky clothing and hair ornaments. Undo hair
- Place feet together with heels, buttocks, and shoulder blades against wall or back of instrument
- Check feet are flat, legs straight, shoulders relaxed, arms hanging loosely
- Gently ease head into correct plane—that is, eyes looking very slightly down so that centre of ear hole is level with lower border of eye socket
- Do not measure a child who is holding his or her breath; encourage normal breathing
- Lower headboard and ensure good contact with head
- Read instrument at eye level to avoid parallax error, rounding down to nearest mm
- Record measurement with care; write figure down and plot height on growth chart
- Note time of day, instrument used, and name of measurer.

Notes
(1) Some allowance must be made in cases where child is knock kneed, or obese.
(2) With very young children, an assistant is required to ensure knees do not bend and heels remain down.
(3) Some practitioners like a weight on the headboard to counteract springy hair. If used, it should be used every time and recorded.

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