Growth is the most sensitive indicator of good health in childhood and height measurement is, therefore a vital part of any clinical examination, writes Prof Hilary Hoey.

Growth is a very sensitive indicator of child health and wellbeing. Normal growth only occurs if a child is healthy, adequately nourished and emotionally secure. Growth impairment may be the first feature to appear in many chronic disorders. Growth measurement is therefore an essential part of the examination or investigation of any child.

The most common growth problems presenting in childhood are short stature and more recently obesity. Early diagnosis of short stature is important as final height in treatable conditions is related to age at which treatment is started. Obesity in childhood is now a major problem in Ireland and worldwide.

Obesity is a chronic, debilitating disease associated with major morbidity and mortality including psychosocial problems, cardiovascular risk and the metabolic syndrome and is generally preventable.

Normal childhood growth

Growth during the first year of life is extremely rapid; birth weight doubles at five months and is tripled by one year: body length increases by 50% in the first year, after which a child’s growth velocity slows down to 4-6cm per year until puberty. At puberty there is a final growth spurt due to the sex hormones, after this growth ceases. Boys have their maximal pubertal growth spurt in the later part of puberty whereas in girls peak growth velocity occurs prior to the onset of menarche, after which girls grow only approximately 5cm.

The infancy-childhood-puberty (ICP) growth model analyses mathematically postnatal growth which appears to be controlled by distinct biological mechanisms. The infancy component from birth to two years is largely nutrition-dependent and also affected by: birth weight and gestational age; genetic background (family height, ethnicity...
etc); social circumstances; seasonal factors; and the statistical phenomenon of ‘regression to the mean’. The childhood component is mostly affected by growth hormone, and the pubertal component depends on synergism between sex hormones and growth hormone. 

Measuring growth in children

Children should be measured in the newborn period including length, weight and head circumference, and also at six weeks. Weight should be measured at five and 10 days and when having immunisations. Length/height and weight should be measured regularly at six months, nine months, 15 months, at two years and annually thereafter.

Accurate measurement is essential to detect growth abnormalities. This requires good regularly calibrated equipment and attention to detail in placing the child in the correct position. The length of children less than two years of age is measured supine using an infantometer or baby mat. Over the age of two years, standing height is obtained with the child standing straight against a wall, bare feet together, shoulders relaxed and looking straight ahead. Gentle traction is applied under the mastoid processes to eliminate the effect of gravity on the spine.

Good measuring equipment is essential for measuring height velocity as the normal growth rate is only 4-6cm per year between the ages of approximately three and 10 years. The most accurate equipment is a wall-mounted Harpenden stadiometer; however, less expensive portable equipment is also available such as the Leicester Height measure. Sitting height is useful to detect disproportion for conditions such as the dyschondroplasias, eg. achondroplasia, hypochondroplasia, where the head and trunk measurement are normal, but the limbs are disproportionately short.

Weight should be measured in the minimum of clothing on a regularly calibrated electronic scales. However, compared to height, the variations in weight during the day are enormous due to water balance, and weight is therefore a less valuable index of growth than height. Skinfold thickness is also useful as children who lack thyroid or growth hormones tend to be small and fat, whereas children with chronic infection or coeliac disease are small and thin.

The measurement is evaluated by plotting the reading on the appropriate growth centile chart for the community. Centile charts show the normal range of height and weight for a child at any age. The 50th centile is the mid-centile line indicating that 50% of normal children fall above and below this line. The highest and lowest lines are the 97th and third centiles and any children who fall above or below these lines should be considered for referral to a growth clinic.

The parents’ height is also important in the assessment of a child, as height is genetically inherited. The height of both parents is plotted on the chart at 19 years with the following

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Table 1

**Causes of short stature**

<table>
<thead>
<tr>
<th>A. Normal variant:</th>
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<tbody>
<tr>
<td>– Familial or genetic short stature</td>
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<tr>
<td>– Intrauterine growth retardation</td>
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<td>– Constitutional growth delay</td>
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B. Pathological causes:

| – Nutritional deficiency               |
| – Chronic infection                    |
| – Malabsorption                        |
| – Chromosomal disorders                |
| – Skeletal dysplasias                  |
| – Chronic illness                      |
| – Psychosocial deprivation             |

Endocrine:

| Growth hormone deficiency              |
| Hypothyroidism                          |
| Glucocorticoid excess                   |

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1. Overview/Hoey-NH 2

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adjustment made for the sex of the child: 12.5cm is subtracted from the father’s height if the child is a girl; and 12.5cm is added to the mother’s height if the child is a boy. The mid-point between these two measurements is called the mid-parental height and the child’s centile line (target height) should fall within 8.5cm either side of this centile line. Any child whose centile line is more than 8.5cm below the mid-parental line may not be achieving its full genetic potential.

**Growth velocity**

The most valuable measurement of growth is the height velocity, which is the gain in height over a period of time. In order to determine the height velocity, two measurements are needed, ideally at a year's interval, as there are seasonal variations in growth; children tend to grow more in the spring and summer than they do in the autumn and winter; and intercurrent mild illness may cause a transient fall in height velocity followed by a catch-up period after recovery from the illness. Poor height velocity is an indicator of an organic cause which should be sought, whereas the child with a normal height velocity is a normal child with normal variant short stature.

**Growth charts**

Growth charts provide an important educational and empowerment tool for children and their family. The growth charts appropriate for Irish children are the Irish tempo-conditional longitudinal growth charts for children aged two to 18 years and for the younger children the new UK-WHO growth charts (0-4 years which include standards from 32 weeks gestation). The Irish growth charts for children aged two to 18 years provide tempo-conditional longitudinal height reference data and are appropriate for Irish children. They differ from the UK nine centile charts for older children in that the Irish charts are longitudinal while the UK charts are cross-sectional and less appropriate for monitoring the growth of an individual child, particularly at puberty. In addition, in the UK older children are heavier, the Irish 97th centile for weight being approximately equivalent to the 91st for UK children. The 99.6th centile for older UK children is approximately 20kg greater than the Irish top centile line which is the 97th centile. This additional weight reflects a greater body weight among UK children and if incorporated within the normal range for Irish children could encourage obesity, which is already a major problem in the Irish population. Assessment of childhood obesity should be based on national Irish reference data.

A weight more than two centiles (2SDs) above the height centile line suggests the need for careful clinical assessment for obesity. Body mass index charts enable the definition of overweight and obesity which differs with age, gender and pubertal status. A BMI above the 91st centile for age indicates overweight and above the 98th centile obesity. However, interpretation must be made in relation to these, as well as to body build and clinical wellbeing.

Disease-specific growth charts are available for many conditions including Down’s syndrome.

**Bone age**

An x-ray of the hand and wrist illustrates the maturity and bone growth or bone age which is an indicator of growth potential. The child with genetic short stature will have a bone age consistent with his chronological age, whereas a child with constitutional growth delay or a systemic disorder will have a delayed bone age indicating potential for catch-up. In children under the age of 18 months, knees and ankles are used.

**Causes of short stature**

The definition of short stature is arbitrary, but children with the following features fall in to this category: a height below the third centile for the community, a height below genetic potential for family height and a child whose height is falling from his centile line to a lower one. Although most cases of short stature are a normal variant due to genetic reasons or to constitutional growth delay, short stature may be the first indication of a treatable systemic illness and, as treatment is only
effective if started well before the epiphyses close at puberty, early diagnosis is essential.

**Normal variant**

In the normal variant group, constitutional growth delay is the most common cause. These are the slow developing children who are small and have a late puberty. They therefore go on growing for a longer period before their pubertal growth spurt, so that they catch up and have a good normal adult height. There is often a family history of growth delay or late puberty. The two other main causes are:
- Familial or genetic short stature where either parent is short
- Intrauterine growth retardation, where the child is born small for gestational age, then grows with a normal height velocity and has a short adult height usually within the normal range. However, 10% of children born small for gestational age fail to catch up by the age of four years and may benefit from growth hormone treatment. 18,19

**Pathological causes**

Approximately 25% of children referred with short stature have a pathological cause. They usually have clinical signs or a poor height velocity which may be the major diagnostic clue. They require early investigation so the cause can be determined and early treatment instituted where possible. The main pathological causes of short stature are listed in Table 2:
- Nutritional deficiency – worldwide, protein-calorie malnutrition is the most common cause of growth failure
- Chronic infection involving any organ system may result in poor growth
- Malabsorption, eg. coeliac or other gastrointestinal disorders such as Crohn’s disease or ulcerative colitis
- Chromosomal disorders such as Turner’s syndrome where short stature may be the only clinical feature and other syndromes such as Noonan’s syndrome which occurs in both boys and girls
- Skeletal dysplasias usually have disproportionate body measurements and may have other clinical features also
- Chronic illness such as renal disorders or congenital heart disease may inhibit growth
- Psychosocial deprivation may present solely as short stature associated with poor height velocity
- Endocrine causes of short stature include growth hormone deficiency, hypothyroidism and glucocorticoid excess. These children grow with a poor height velocity and have a greater weight and skinfold thickness than that for height.

**History**

A full medical and social history, including birth weight and gestational age, developmental milestones, psychological wellbeing, growth rate and specific questions related to aetiology of short stature listed in Table 1.

A family history should include height of parents and sibling and also timing of puberty together with a history for any general illnesses.

**Physical examination**

A complete physical examination is required including growth measurement to assess height, weight, head circumference, sitting height and staging of puberty if signs are present. Blood pressure, fundi and visual fields must be assessed and other more specific findings sought, such as the presence of small external genitalia in a male, suggesting pituitary deficiency and café au lait spots or freckling, suggesting neurofibromatosis, dysmorphic features, signs of malabsorption, renal disease or congenital heart disease.

**Investigations**

Investigations of poor growth are summarised in Table 2.

**Growth hormone tests**

Tests of growth hormone secretion are considered if there is short stature, poor height velocity (ideally over a 12-month period) and when initial assessment and investigations fail to reveal a cause for the short stature. Growth hormone is secreted in a pulsatile manner approximately
Table 2

Investigations of poor growth

- Bone age
- Karyotype (girl’s height below 3rd centile to exclude Turner’s syndrome)
- Specific investigations (when indicated):
  - Full blood count, ESR
  - Electrolytes, creatinine, bicarbonate, calcium, phosphate, alkaline phosphatase and liver enzymes
  - Gastrointestinal to include stool culture, coeliac antibodies and barium studies may be indicated to diagnose Crohn’s disease or ulcerative colitis.
  - Endocrine tests:
    - Thyroid function including TSH and free T4 levels
    - Gonadotrophin releasing hormone test
    - Diurnal cortisol levels
    - Growth hormone provocation tests and IGF levels
    - Radiology: MRI to exclude a brain tumour in growth hormone deficiency

Four-hourly, most frequently during sleep and in between times there are very low blood levels. A random growth hormone level is therefore of little value and a provocation test is required. The stimulus used can be physiological or pharmacological. Exercise is a physiological stimulus and blood is taken 20 minutes after controlled exercise. If the serum growth hormone level rises to 5µg/l or greater the growth hormone levels is considered normal; and if the blood level is less than 5µg/l the child proceeds to a pharmacological test.

Pharmacological stimulation tests are not without danger and must be performed with very close medical supervision, and laboratory results must be interpreted with caution due to inter-assay and inter-laboratory variability problems. These include the insulin hypoglycaemia test which must have a doctor in attendance and following intravenous insulin blood is taken at 15-minute intervals for 90 minutes. This test should only be performed in specialised growth assessment centres because of the risk of profound hypoglycaemia or rebound hyperglycaemia. Other pharmacological tests include Levodopa propranolol; glucagon; clonidine; arginine; growth hormone releasing hormone (GHRH or GRF test) and the IGF1 generation tests. IGF1 and IGFBP3 are usually low but are not diagnostic in isolation of growth hormone deficiency/ insufficiency in childhood.

Other physiological tests include a 24-hour growth hormone profile taking blood at 20 minute intervals; however, this is traumatic for the child and involves considerable clinical, laboratory and staff time. This is, however, a vital test in certain circumstances but unsuitable for initial screening.

In patients who are in the immediate pre-puberty age range with little to no signs of puberty, there is often a blunting of the growth hormone response to conventional provocation. The use of a single intramuscular dose of 100mg of mixed testosterone ester in boys three to five days before the growth hormone provocation, and in girls the administration of ethinyloestradiol...
in a daily dose of 100µg/day for three days prior to the test will usually produce a normal response in those who are not growth-hormone deficient.

Radiology including a bone age x-ray and an MRI brain scan may be indicated in growth hormone deficiency to study the pituitary gland or exclude a brain tumour

**Treatment**

Treatment aims to correct the underlying problem where possible (eg. gluten-free diet for coeliac disease, thyroxine in hypothyroidism). The earlier the treatment the better the final height.

Growth hormone treatment is given as a daily (bedtime) subcutaneous injection to children with growth hormone deficiency. It is also approved by the National Institute of Clinical Excellence (NICE) for the treatment of Turner’s syndrome, Prader Willi syndrome, chronic renal insufficiency, short stature homeobox-containing gene (SHOX) deficiency and in children born small for gestational age who fail to have a ‘catch-up’ growth spurt at the age of four years or older.

Monitoring of growth hormone therapy includes: careful growth monitoring with particular focus on height velocity; monitoring for other pituitary deficiencies which may evolve or be unmasked during therapy; monitoring of IGF1 and IGFBP3 levels during therapy to guide replacement and avoid over-treatment and the assessment of glucose intolerance particularly in the high-risk groups, eg. Turner and Prader Willi syndromes.

The potential side-effects of growth hormone treatment are glucose intolerance, hyperinsulinism, hyperlipidaemia or hypertension. Leukaemia may be more common in growth hormone-deficient children treated with growth hormone, but there is currently no evidence causally linking treatment with leukaemia, or evidence that tumour recurrence or second tumours are more common.

**Psychological support**

The treatment of short stature should aim not only to promote growth and final height but also to alleviate any psychosocial problems. The child and family require early psychological counselling and the child requires encouragement and a supportive environment. Short children must be treated in accordance with their age and not their size; tall children have been shown to mature earlier as they are given more responsibility, whereas small children mature later as they are treated as being less able.

**Tall stature**

Children with tall stature, ie. above the 97th centile, are usually so because of genetic reasons – they simply have tall parents! This is referred to as constitutional tall stature.

However, tall stature may also be associated with precocious puberty or various paediatric syndromes that require specialist assessment such as Marfan syndrome, Soto’s syndrome and Kallman’s syndrome. Family history including careful assessment of the child for clinical abnormalities and dysmorphic features is required.

**Conclusion**

Growth is the most sensitive indicator of good health in childhood and height measurement is therefore a vital part of any clinical examination. Where there is a treatable cause of poor growth, the earlier the diagnosis and treatment the better the final adult height and weight.

If the cause is untreatable, it is important to discuss the problem with the parents and the child in order to minimise and avoid psychological disturbances that may result.

Every child should have regular growth assessments. If their height is below the third centile for the average developer, referral should be considered to a growth clinic. The child will then have a full history and physical examination and if this is abnormal, he/she will be investigated immediately. However, if the history and examination are normal the child will be measured again after one year with a stadiometer. If at this time the child’s velocity is poor, he/she will be fully investigated. Alternatively, if the velocity is normal there is no need for further follow-up.
The prevention and treatment of obesity requires early detection, education and empowerment of families relating to diet and exercise, along with regulation and control on food marketing and clear nutritional labelling.20

Much can be done, particularly in relation to child health surveillance and early detection of growth disorders, including obesity, to reduce long-term expensive morbidity in adulthood. Our great challenge in the 21st century is to prevent the development of adult diseases, which have their origin in childhood.

Professor Hilary Hoey is a consultant paediatric endocrinologist and emeritus professor of paediatrics at Trinity College Dublin

References
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4. Roche E. Childhood Obesity. IMJ 2003; 96: 4, 100-102
15. Hulse JA, Shilg S. Relation between height and weight centiles may be more useful. BMJ 1996; 312: 122
16. OSCA (Obesity Services for Children and Adolescents) Guidelines and obesity assessment protocol www.rcpch.ac.uk

Where to get your growth charts

- Irish growth charts for height and weight for children aged 2-18 years are available from Castlemead Publications, Brickendonbury, Brickendon Lane, Hertford SG13 NP United Kingdom. Tel:01992505692, Fax 01992 500076, Website: www.castlemeadpublications.com
- Growth charts for infants from 0-4 years UK/WHO and BMI charts are available from Harlow Printing Limited, Maxwell Street, South Shields, Tyne And Wear, NE33 4PU, United Kingdom Email: www.sales@harlowprinting.co.uk
- Growth charts for boys and girls as well as growth and development records for boys and girls are also available in the ICGP Yearbook and Diary