

Normal and abnormal puberty (Stages and assessments)

See also the separate [Delayed Puberty](#) and [Precocious Puberty](#) articles.

What is puberty?

Puberty is the process by which a child's body develops into an adult body and becomes capable of reproduction. It involves physical growth and sexual and psychosocial maturation. Growth accelerates in the first half of puberty and stops at the completion of puberty. Puberty usually begins between 8 and 14 years of age in girls and 9 and 14 years of age in boys. Data indicate that onset of puberty has been gradually becoming slightly earlier, both in boys and in girls^[1] ^[2]. This may or may not be related to the rise in obesity and remains a subject of debate and research.

Although girls are generally considered to mature earlier than boys, the differences in timing are less than generally perceived. Testes require higher levels of gonadotrophin stimulation than ovaries - hence, the later puberty. However, on average, spermatogenesis occurs at about the same time as menarche with attainment of reproductive capability being achieved at about the same age.

Normal puberty^[3]

The onset of puberty is signalled by the secretion of increasing frequency and amplitude of pulses of gonadotrophin-releasing hormone (GnRH). Activation of the hypothalamic-pituitary-gonadal system leads to the changes of puberty, via production of GnRH, luteinising hormone (LH) and follicle-stimulating hormone (FSH), and subsequently testosterone or estradiol. The phases of development are conventionally described in 'Tanner stages' (see tables below)^[4].

It should also be remembered that aside from physical change, puberty is associated with enormous mental and emotional changes. The individual is developing their personality and creating themselves an identity outside the family. He or she must come to terms with physical change, and negative self-image is a common issue.

Normal puberty in girls

- Breast enlargement, occasionally initially unilateral, is the first obvious sign of puberty. Breast buds may initially be unilateral. Gradually the breast diameter increases and the areola darkens and becomes more prominent. In the UK, breast buds will have appeared in 50% of girls by the age of 11.3, with near-full development in 50% of girls by the age of 13.3^[5] .
- Pubic and axillary hair growth in girls is a sign of adrenal androgen secretion. It starts at about the time of apocrine gland sweat production and the common complaint of axillary odour.
- Menarche usually occurs about 2–3 years after the start of breast development (thelarche). In one British cohort study the average age at menarche was 12.9 years and the average duration of puberty was 2.7 years^[6] . This figure is unchanged in a more recent UK cohort^[7] .
- The growth spurt occurs earlier in female puberty. It is usually maximal (about 8 cm/year) during Tanner's breast stages 2 and 3. and reduces to 4 cm/year at menarche.

Examination

- May reveal pubic hair and changes in the vaginal mucosa (from red prepubertally to pastel pink, moist mucosa of the oestrogenised vagina).
- Vaginal examination should only be performed if the patient is already sexually active.
- Rectal examination should never be performed (information better from ultrasound).
- Breast examination: supine position to help distinguish true breast enlargement from fat.
- Skin: mild acne in early puberty is normal; however, rapid onset and progression of acne again suggest androgen excess.
- Clitoral enlargement and severe acne suggest androgen excess and virilisation.

Puberty stages in girls

Tanner's stages of puberty in girls are summarised in the table below.

Tanner stage	Breasts	Pubic hair	Growth	Other	Other
Stage 1	Prepubertal - elevation of papilla only.	Prepubertal villus hair only.	Basal level - 5 cm to 6 cm per year.	Adrenarche.	Ovaries grow and enlarge.
Stage 2	Breast bud appears under an enlarged areola (mean age 11.2 years).	Sparse hair along labia (mean age 11.9 years).	Accelerated growth - about 7 cm to 8 cm per year.	Clitoral enlargement with labial pigmentation.	Uterine enlargement.
Stage 3	Breast tissue grows beyond areola but without contour separation (mean age 12.4 years).	Hair coarser and pigmented - spreads across pubes (mean age 12.7 years).	Peak velocity - about 8 cm per year (mean age 12.5 years).	Axillary hair (mean age 13.2 years).	Acne (mean age 13.2 years).
Stage 4	Projection of areola - papilla forms a secondary mound (mean age 13.1 years).	Adult pattern but without spread to medial thigh (mean age 13.4 years).	Deceleration - less than 7 cm per year.	Menarche (mean age 13.3 years).	Regular periods (mean age 13.9 years).

Stage 5	Adult breast contour with projection of papilla only (mean age 14.5 years).	Adult with spread to medial thigh but not up linea alba (mean age 14.6 years).	Cessation of growth at around 16 years.	Adult genitalia.	
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Normal puberty in boys

- The first signs of puberty often go unnoticed. Testicular enlargement can be detected quite early but is often subtle enough in the early stages to go unnoticed. It usually occurs between the ages of 12 and 13 years. The prepubertal testis is about 2 ml in volume with puberty taken to begin when a volume of around 4 ml is attained.
- Testicular growth starts as early as 10 years of age, associated with enlargement of seminiferous tubules, epididymis, seminal vesicles and prostate gland.
- Enlargement of testes depends on increased FSH. Prader's orchidometer (a string of different volume 'beads'/testes for comparison by the examiner) can be used to assess testicular size.
- Spermatozoa become present in early-morning urine samples from a mean age of 13.4 (spermarche).
- Progressive signs of androgen excess without an increase in testicular volume should raise concern about precocious pseudopuberty (androgenic effect from another source such as congenital adrenal hyperplasia or testicular tumour).
- Penile and scrotal enlargement occur typically about a year after testicular enlargement is noticed.
- Signs of change in penis (growth), scrotum (reddening and thinning) and pubic hair growth follow 1-2 years after testicular enlargement.
- Pubic hair typically appears at a similar time.
- Pubic hair growth without other changes (premature adrenarche) suggests adrenal androgen production (congenital adrenal hyperplasia (CAH), Cushing's syndrome, adrenal tumour).
- 50-90% of boys have some degree of breast hypertrophy.

- Later signs include growth spurt, voice deepening, acne and facial hair. The growth peak starts 2-3 years earlier in girls. Growth spurts start with the hands and feet and move proximally to finish with the trunk.
- A greater and later growth spurt occurs in boys than in girls. The growth spurt is on average two years later than that of girls and ceases only one year later.

Puberty stages in boys

Tanner's stages of puberty in boys are summarised in the table below.

Tanner stage	Genitalia	Pubic hair	Growth	Other
Stage 1	Prepubertal - testes less than 2.5 cm.	Villus hair only.	Basal rate - 5 cm to 6 cm per year.	Adrenarche.
Stage 2	Thinning and reddening of scrotal skin (mean age 11.9 years). Testes 2.5 cm to 3.2 cm.	Sparse growth base of penis (mean age 12.3 years).	Basal rate as above.	Reduction in total body fat.
Stage 3	Growth of penis (mean age 13.2 years). Testes 3.3 cm to 4 cm.	Thicker hair - spreads to mons pubis (mean age 13.9 years).	Accelerated growth - 7 cm to 8 cm per year.	Gynaecomastia (mean age 13.2 years). Voice break (mean age 13.5 years). Increase in muscle mass.
Stage 4	Growth of penis and glans with darkening of scrotum (mean age 14.3 years). Testes 4.1 cm to 4.5 cm.	Adult but no spread to medial thigh (mean age 14.7 years).	Peak velocity about 10 cm per year (mean age 13.8 years).	Axillary hair (mean age 14 years). Voice change (mean age 14.1 years). Acne (mean age 14.3 years).
Stage 5	Adult genitalia (mean age 15.1 years). Testes greater than 4.5 cm.	Adult with spread to medial thigh but not linea alba (mean age 15.3 years).	Deceleration and cessation (about 17 years).	Facial hair (mean age 14.9 years). Muscle mass increases further and beyond Stage 5.

Assessment of abnormal puberty^[8]

There are many causes of abnormal puberty. The main aim of assessment is to determine those children with an underlying pathological abnormality from those with constitutional and benign pubertal changes. It is important to recognise abnormal timing and progression of puberty. This may require a combination of clinical assessment, investigations and expert advice.

History

- Take a full history of previous growth and development.
- Record the timing and sequence of physical milestones and behavioural changes of puberty.
- Record full medical and surgical history, including a medication history.
- If the individual is underweight and has delayed puberty take a nutritional history.
- Detail any family history of early or delayed puberty and any genetic disease.

Physical examination

- The genitalia, breasts and body habitus should be examined and the stage of puberty documented.
- Plot growth velocity on a [growth chart](#). Note whether there has been a change compared with old records.
- Make a neurological and endocrine assessment:
 - Look for evidence of thyroid or other endocrine dysfunction.
 - Optic fundi, visual fields and sense of smell should be checked to look for evidence of a pituitary tumour.
- Photographs may be useful to document the stage of puberty and for future reference. However, such clinical photographs need appropriate consent and are best undertaken in hospital medical photography departments.

Investigation^[8]

Investigations should be used selectively and based on a thorough clinical assessment.

- Blood tests may include FSH/LH levels, oestrogen assay, testosterone levels, prolactin levels, insulin-like growth factor I, beta human chorionic gonadotrophin (beta-hCG) and TFTs.

- Molecular karyotyping may be required to exclude chromosomal disorders such as [Klinefelter's syndrome](#) or [Turner syndrome](#).
- GnRH stimulation test and other tests of pituitary function (see the separate [Pituitary Function Tests](#) article).
- Diagnostic imaging may include:
 - X-ray of the left wrist can be used to determine skeletal age compared with chronological age.
 - Pelvic ultrasound: essential in gonadotrophin-independent precocious puberty (precocious pseudopuberty) in girls to detect [ovarian tumours](#) or cysts.
 - Testicular ultrasound: to detect tumour.
 - Adrenal ultrasound: to detect tumour; however, there is much better imaging with MRI scan.
 - Brain MRI scan: for those with neurological signs or symptoms or where a central cause is suspected.

Further reading

- [Ojeda SR, Lomniczi A, Mastronardi C, et al](#); Minireview: the neuroendocrine regulation of puberty: is the time ripe for a systems biology approach?; *Endocrinology*. 2006 Mar;147(3):1166-74. Epub 2005 Dec 22.
- [Shalitin S, Gat-Yablonski G](#); Associations of Obesity with Linear Growth and Puberty. *Horm Res Paediatr*. 2021 Jun 15:1-17. doi: 10.1159/000516171.

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