Physical growth and development during adolescence

Kym Ahrens, MD, MPH
Assistant Professor, Adolescent Medicine
UW/Seattle Children’s
“At your age, Tommy. A boy’s body goes through changes that are not always easy to understand.”
**Definitions**

- **Adrenarche** = activation of the adrenal cortex → produce adrenal androgens (typically occurs before the onset of puberty).

- **Gonadarche** = activation of the gonads by the pituitary hormones follicle-stimulating hormone (FSH) and luteinizing hormone (LH)

- **Pubarche** = appearance of pubic hair

- **Thelarche** = appearance of breast tissue

- **Menarche** = age of onset of the first menstrual period

- **Spermarche** = age at first ejaculation (heralded by nocturnal sperm emissions and appearance of sperm in the urine)
Features of Puberty

- Physical change reflects hormonal change
- Order of changes similar for both sexes
- Onset: Girls: 7 to 13 years*
  Boys: 9 to 14 years
- Timing and rate:
  - ~ 5 years females; ~6 years males
  - Differs by gender & ethnicity
- Length of puberty
  - Boys: 4-6 years (mean 4.2)
  - Girls: 3-4 years
Trigger for puberty?

- Not clear—probably 50-80% of variation in onset = genetics

- Change in body composition = permissive role (Leptin)

- A threshold percentage of body fat is likely necessary but not sufficient for onset (↓ Leptin → ↓ LH pulse → pubertal suppression)
The Start of Puberty

- Body Clocks controlled by “master genes”?

- Inhibitory central feedback maybe mediated by GABAergic or neuropeptide Y-secreting neurons

- GnRH pulse generator becomes increasingly active, first nocturnally then during day
Hormones of Puberty

- H-P-G Axis
- Adrenal system
In the fetus: GnRH, gonadotropins and gonadal steroids present at 10 weeks gestation

At birth, placental sex steroids decrease, leading to a rise in pulsatile release of gonadotropins and hence of gonadal steroids during infancy
Low levels of sex steroids exert powerful negative feedback on the hypothalamus, suppressing gonadotropin release.

In addition, the CNS exerts a separate inhibitory effect on hypothalamic secretion of GnRH.
Disinhibition of the GnRH neurons by the CNS—leads to pulsatile release of GnRH

- sensitivity of H to gonadal steroids leads to LH/FSH secretion.

- Increased LH and FSH lead to testosterone and estrogen.
<table>
<thead>
<tr>
<th></th>
<th>LH</th>
<th>FSH</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MALES</strong></td>
<td>• Testosterone production $\rightarrow$ Leydig cells</td>
<td>• Sperm production $\rightarrow$ Sertoli cells</td>
</tr>
</tbody>
</table>
| **FEMALES** | • Androgen production $\rightarrow$ theca cells  
• Progesterone production $\rightarrow$ corpus luteum  
• Mid-cycle surge $\rightarrow$ ovulation | • Ovarian follicle dev  
• Estrogen production $\rightarrow$ granulosa cells |
<table>
<thead>
<tr>
<th>TESTOSTERONE</th>
<th>MALES</th>
<th>FEMALES</th>
</tr>
</thead>
<tbody>
<tr>
<td>TESTOSTERONE</td>
<td>• Growth of penis and scrotum</td>
<td>• Thickening of cortical bone</td>
</tr>
<tr>
<td>MALES</td>
<td>• Growth of pubic/facial hair</td>
<td>• Growth of pubic hair</td>
</tr>
<tr>
<td></td>
<td>• Deepening of voice</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Increased libido</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Increased muscle mass</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Acne</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Thickening of cortical bone</td>
<td></td>
</tr>
<tr>
<td>ESTROGEN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| **MALES**  
Peripheral conversion | Important bone effects:  
• Low levels: pubertal growth spurt, accrual of peak bone mass  
• Higher levels: closure of the epiphyses |
| **FEMALES** | • Bone effects as in males  
• Growth of breasts, labia, vagina, uterus  
• Pattern of fat deposition  
• Vaginal pH ↓ and vaginal length ↑  
• Proliferation of the endometrium  
• Triggers LH surge |
Adrenal System

- **Adrenarche**: Secretion of adrenal steroids from the zona reticularis of the adrenal gland cortex
  - Typically precedes ↑ in gonadal steroids by 2yrs
  - Independent of HPG axis
  - Trigger unknown
  - Effects: Pubic/axillary hair, body odor, acne

Conversion in body:
- DHEA
- DHEAS
- Androstenedione
- Estrone
- Testosterone
Pubertal Timing

- Sequence is predictable
- Timing is highly variable
- Chronological age correlates poorly with biological maturity
- Best to assess maturity by tanner staging or skeletal age/bone age
- Often asynchrony between breast/genitalia and pubic hair → slight lag in HPA axis
Jeff: Tanner stage V

Pete: Tanner stage II
Too early, too late

Breast Changes:
- Early < 7 in girls
- Late > 13 in girls

Pubic Hair:
- Early < 7 in girls
- Late > 13 in girls

Menarche:
- Too late > 16 (or > 5 yrs from TS-II breasts)

Gonad changes:
- Early < 9 in boys
- Late > 14 in boys

Pubic Hair:
- Early < 9 in boys
- Late > 15 in boys

Duration of Puberty:
- Too long > 5 yrs from TS II-V
Spectrum of Precocious Puberty

Benign Mild
Incomplete

Pathological
Precocious Puberty

Slow progression
Uncertain
Fast progression

Premature thelarche
Premature adrenarche

Minimal impact on adult height

Minimal impact on timing of menstruation

Minimal social/emotional distress

Central precocious puberty
Peripheral precocious puberty

Negative impact on adult height

Early menstruation

Social/emotional distress
Early Puberty

- Higher self-esteem
- Greater social approval
- Earlier onset sexual behavior

- More body dissatisfaction
- Lower self esteem
- Earlier onset sexual behavior
Puberty – Getting Earlier?

Menarche:
- 1850s→1950s - mean age of menarche ↓ from 17 yrs→<14 yrs in U.S./Western Europe
- Timing of menarche relatively stable since 1960s in U.S.

Breast Development:
- ? ↓ since the 1970s in the United States:
  1970s : age 8
  1997 : age 7 (white girls) and age 6 (African Am girls)

→ ? Due to changes in nutritional, health, & SES, other causes?.
Physical Growth: Rate

- Average normal growth velocities:

<table>
<thead>
<tr>
<th>Year</th>
<th>Velocity (cm/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st year</td>
<td>25</td>
</tr>
<tr>
<td>2nd year</td>
<td>10</td>
</tr>
<tr>
<td>3rd year</td>
<td>8</td>
</tr>
<tr>
<td>4th year</td>
<td>7</td>
</tr>
<tr>
<td>5th to 10th year</td>
<td>5</td>
</tr>
<tr>
<td>Puberty</td>
<td>8-10</td>
</tr>
</tbody>
</table>
Height velocity by age for American boys. Red line: 50th centile for boys maturing 2 SD earlier than the mean; Green line: 50th centile for boys maturing 2 SD later than the mean. Other lines show the 3rd (purple) through 97th (blue) centiles for boys maturing at an average time.


Height velocity by age for American girls. Purple line: 50th centile for girls maturing 2 SD earlier than the mean; Yellow line: 50th centile for girls maturing 2 SD later than the mean. Other lines show the 3rd (red) through 97th (blue) centiles for girls maturing at an average time.

Sequence of puberty in boys

Sequence of pubertal events in boys with average timing of pubertal development in the United States.
Sequence of puberty in girls

Sequence of events in girls with average timing of pubertal development in the United States. Black girls tend to reach a milestone at a younger age (left-hand side of the bracket) than white girls (right-hand side of the bracket). The median length of time between the onset of puberty (breast Tanner stage 2) and menarche is 2.0 years, and the 95th percentile is 4.5 years.

Body Composition

Important Sex Differences

![Graphs showing muscle mass and body fat changes with age for males and females.](Steinberg, Adolescence, 4e. Copyright © 1996. McGraw-Hill Companies, Inc. All Rights Reserved.)
Timing of puberty in white and black girls in the United States

In this study, the first signs of puberty occurred at a younger age than had been previously reported; the mean age of onset was earlier for black versus white girls.

Tanner staging of pubic hair development in boys

Stages of pubic hair development in boys. Stage 1: Prepubertal, with no pubic hair. Stage 2: Sparse, straight pubic hair along the base of the penis. Stage 3: Hair is darker, coarser, and curlier, extending over the mid-pubis. Stage 4: Hair is adult-like in appearance, but does not extend to thighs. Stage 5: Hair is adult in appearance, extending from thigh to thigh.

Tanner staging of breast development in girls

1A

1B

2A

2B

3A

3B

4A

4B

5A

5B

Stages in breast development in girls.
Stage 1: Prepubertal, with no palpable breast tissue.
Stage 2: Development of a breast bud, with elevation of the papilla and enlargement of the areolar diameter.
Stage 3: Enlargement of the breast, without separation of areolar contour from the breast.
Stage 4: The areola and papilla project above the breast, forming a secondary mound.
Stage 5: Recession of the areola to match the contour of the breast; the papilla projects beyond the countour of the areola and breast.

Happens:
~2 years before peak height velocity
~4 years before menarche

Tanner stages of pubic hair development in girls

Stages of development in pubic hair in girls.
Stage 1: Prepubertal with no pubic hair.
Stage 2: Sparse, straight hair along the lateral vulva.
Stage 3: Hair is darker, coarser, and curlier, extending over the mid-pubis.
Stage 4: Hair is adult-like in appearance, but does not extend to the thighs.
Stage 5: Hair is adult in appearance, extending from thigh to thigh.

The Perils of Puberty...
Clinical Question:

A 14yo male comes into your office. You detect upon walking into the room that he needs to start wearing deodorant. You also note that he has some mild facial acne and some axillary hair.

- Should you conclude that he is going through puberty normally?
- Which system causes these changes?
Answer:

Not necessarily.

These are all signs that his **adrenal system** is producing hormones, but does not tell you anything about the H-P-G axis.
- Usually normal BUT can be a source of low self-esteem
- Caused by the ______  ______
- Severe acne + other signs/symptoms of androgen excess:
Acne

- Usually normal BUT can be a source of low self-esteem
- Caused by the adrenal system
- Severe acne + other signs/symptoms of androgen excess:

  → Consider endocrine disorder, e.g. NON-CLASSIC CONGENITAL ADRENAL HYPERPLASIA
Clinical Question:

A 12 yo male presents with pain and swelling in his right nipple.

- What do you want to know?
- What can you tell him about this condition?
Answer:

What you want to know:

Is puberty progressing normally?
Is he on any medications?
Any chronic illnesses?
Gynecomastia

- Glandular development due to changes in hormone levels during puberty (estrogenic-androgenic balance)
- 1/3 of healthy guys
- Usually resolves in 3-24 months without intervention.
- Assessment/management:
  - Careful history for common drug culprits or chronic diseases (liver dz)
  - PE to assess for true vs. pseudogynecomastia
  - Monitor every 3-6 months until resolved
  - Consider SERM, surgical referral if: Lasts longer than 12 mos, causing discomfort/embarrassment, AND adult testicular size has been attained
Common culprits in adolescents:

- Drugs of abuse (alcohol, amphetamines, heroin, marijuana, anabolic steroids)
- Psychoactive drugs (antipsychotics)
- Reflux meds (ranitidine, cimetidine, omeprazole)
- Antifungals/antibiotics (metronidazole, ketoconazole, INH)
Clinical Question:

- An 11 year old soccer playing female comes into your office for a sports physical. Name 2 common musculoskeletal complaints that occur in adolescence and are impacted by skeletal maturity.
**Osgood Schlatter:**
- Caused by overuse → chronic avulsion of tibial tubercle growth plate
- Usually happens in athletic adolescents right after growth spurt (i.e., age 13-14 in boys, age 11-12 in girls)
- Clinical diagnosis: appropriate history, tibial tubercle swelling

**Scoliosis:**
- 80-85% adolescent onset
- Progression more common in girls once diagnosed
- Once skeletal maturity occurs, will not progress
- Indications for referral to an orthopedic surgeon
  - Angle of trunk rotation (as measured with the scoliometer) of $\geq 7^\circ$, Cobb angle $\geq 20^\circ$, and progression of Cobb angle of $>5^\circ$. 
Cobb angle measurement

The Cobb angle (arrow in radiograph) is formed by the intersection of a line parallel to the superior end plate of the most cephalad vertebra in a particular curve, with the line parallel to the inferior end plate of the most caudal vertebra of the curve. The intersection of these lines may occur outside the border of the actual film. Therefore, by convention, perpendiculars to the parallels are drawn, and the angle between their intersection is measured. The Cobb angle in the above radiograph is 63°. The most cephalad vertebra is the vertebra that has the greatest tilt from horizontal of its superior end plate (red line). The most caudal vertebra is the vertebra that has the greatest tilt from horizontal of its inferior end plate (blue line). Drawing lines along several vertebrae near each end of a curve (dashed lines) is helpful in determining that with the greatest tilt.

Radiograph courtesy of Dr. Susan Scherl.
Clinical Question:

This 16 yo female with scoliosis asks you if you think her curve will get any worse.

What do you need to know?
You want to know her Tanner Staging and when she had menarche.

Since she is TS V, and had menarche 4 years ago, she probably will not be growing much more and her curve should not increase.
Other common issues

- Anemia (9% of adolescent girls = iron deficient)
- Myopia (caused by growth in axial diameter of the eye)
- Dysfunctional uterine bleeding (80% due to anovulation)
- STIs (peak incidence of many STIs 15-24 years)
THE CERVIX – CERVICAL ECTOPY

Columnar Epithelium

Squamo-columnar junction

Squamous epithelium

Cervical Ectopy

Fig 21.3
Our favorite puberty books

American Medical Association Girl’s Guide to Becoming a Teen (Kate Gruenwald & Amy B. Middleman) – also boy version

What's Happening to me? (Peter Mayle)

Where Did I Come From? (Peter Mayle)

Will Puberty Last My Whole Life? (Julie Metzger & Rob Lehman)

American Girl’s The Care and Keeping of You (Valorie Schaefer & Norm Bendell)
THANKS!!!!

- David Breland
- Ann Giesel