Adult Height Prediction

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Normal Growth

- Disorders of growth are the commonest reason for referral to a pediatric endocrinologist.
- Growth can be divided into fetal, infancy, childhood and pubertal phases.
- Factors influencing growth in each phase are distinct.
- Growth velocity of up to 62 cm/year during the second trimester and 48 cm/year during the third trimester.
- The fetal phase is the fastest period of growth during the human lifespan.

Normal Growth

- The main endocrine factors of fetal growth are insulin and IGF-I and IGF-II.
- Placental function and maternal nutrition are the most important non-endocrine factors influencing growth during this period.
- Growth hormone (GH) plays only a minor role in growth during intrauterine life.
- Rapid decline in GV during the first year of life from an initial peak velocity of 25 cm/ yr to around 10cm/yr by the end of the first year.
- Growth during this period is dependent on nutrition and thyroid hormone.
- GHD display reduced growth velocity from birth.

Normal Growth

- Size at birth correlates poorly with parental size.
- There is a period of catch-up or catch-down growth over the first 2 years and correlation with parental size.
- Infants and toddlers grow the fastest. The growth rate declines rapidly from birth to roughly age 2 and declines more slowly thereafter.
- Immediate prepubertal years, growth slows with the lowest growth velocity occurring just before the onset of puberty.
- During puberty, the growth rate increases again to a second maximum, after which it slowly declines to zero.

Normal Growth

- Pubertal growth spurt occurs on average 2 years earlier in females and reaches a peak of 8cm/year coinciding with the onset of puberty.

- Peak growth velocity in males reaches 10 cm/year and occurs later in puberty coinciding with a testicular volume of 10–12mL.

- Difference in height between males and females is due to the later onset of the pubertal growth spurt in males with the additional years of prepubertal growth and the greater magnitude of the male pubertal growth spurt.

- On average, female and male growth trails off to zero at about 15 and 18 years old, respectively.

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Normal Growth

- GH, IGF-I and thyroid hormone are the primary drivers of childhood growth.
- Sex steroid production is associated with an increase in activity of the GH/IGF-I axis.
- Growth ceases with fusion of the epiphyseal growth plate that is induced by oestrogen acting on the oestrogen receptor-α.
- A person's height begins to shrink in middle age.
- This is due to factors such as the decreased height of intervertebral discs as well as changes due to degenerative diseases.

What Does a child's Height Depend On?

- Lots of us believe that children are usually taller than their parents.
- That is not a rule, and these trends vary from child to child and from family to family.
- **Individual's height is determined by:**
  1) Genetics
  2) Environmental

Genetics

- The single most significant factor
- **About 60-80% of the individual's height is determined by genetics.**
- Results of a Finnish study on almost 9000 twins: 78 percent for men and 75 percent for women.
- The heritability varies even for men and women.
- This means that very tall or short parents are likely to have a taller or shorter child than average, but the child is likely to be closer to the average height than their parents

In Asian and African populations, the height heritability is notably lower.

What Does a Child's Height Depend On?

- **Environmental**

- Environmental factors (especially nutrition) is estimated to be around 20-40%.

- These values may vary a lot between ethnic populations as well. This is mainly due to different living environments (including nutrition, lifestyle, and climate conditions) and different genetic combinations across communities.

- Aspects still have a lot of impact on the child's height

A) Nutrition – growth requires a lot of energy, eat well (provide enough macronutrients and micronutrients to the developing body).

- Overweight children tend to be taller than others, but staying fit is crucial for their development.

- Eat as many unprocessed foods as possible such as fresh fruits, vegetables, whole grains, proteins, and dairy.

- Avoid eating foods that are high in sugar, trans fats, saturated fats, and sodium.

What Does a Child's Height Depend On?

B) Sleep Enough

- Sleep regularly. Human growth hormone, a factor that affects growth, is released while you sleep. A regularly poor sleeping schedule during adolescence can affect growth in the long term. How much a person should sleep is dependent on their age, with more sleep being recommended the younger the child.

C) Sports Activities

- Exercise regularly to strengthen bones and muscles, maintain a healthy weight, and reduce the risk of diseases such as osteoporosis and other issues that could arise from poor health, which could in turn affect growth and height.
- Pay attention to good posture. Aside from looking shorter due to poor posture, it can affect actual height in the long term if the back starts curving to accommodate a regular slouching posture.

What Does a Child’s Height Depend On?

D) Health

- Particularly in puberty sport.
- Health and age of the mother during pregnancy.

E) Hormone levels, especially growth hormone or thyroid hormones.

F) Medications, such as corticosteroids.

- **Genetic conditions:** Children with Marfan's syndrome tend to grow higher, while children with Down's syndrome are usually shorter than others.

What Does a Child's Height Depend On?

- Herit ability allows us to consider how the person's height is determined. Let's analyze it on the following example: a **man who is 183 cm tall.**

- The white male population has an average height of 178 cm with a heritability of 80 percent.

- Our individual is 5 cm taller than the population average.

- Analysis of heritability suggests how much of his extra height is a genetic cause and how much is due to environmental factors In this example, we can say that 4 cm of his extra height is thanks to genetics (80%), and the 1 cm (20%) is an environmental effect (probably a result of good nutrition).

- **Can identical twins be different heights?**

  Yes, identical twins can be of different heights. This is because a small percentage of the factors that determine height are **environmental**, so if one twin receives a more nutrient-rich diet, they will likely be taller, even though they are genetically the same

Adult Height Prediction

- Predicting a child's adult height
- Many different methods have been developed to predict a child's adult height, some more accurate than others.

- Some use mathematical estimations as a base and are entirely safe.

- Regardless of how accurate the method, height prediction is not an exact science, and it is possible that a child's height can deviate significantly from what is predicted.

A) Simple methods

Very simple, but less accurate.

Adult Height Prediction

1) The mid-parental child height formula

- The mid-parental formula is the easiest way to calculate a child's height based on the parents' height

(mother's height + father's height)/2

- For a **girl's future height**, subtract 2½ in (or 6.5 cm)
- Girl's height = mid-parental height - 2½ in (or 6.5 cm)
- For a **boy's future height**, add 2½ in (or 6.5 cm)
- Boy's height = mid-parental height + 2½ in (or 6.5 cm)
- You can expect a **margin of error of about four inches** either way.
- A child's height is primarily determined by genetics. However, it does not depend solely on the parents' height. It's inherited in a way so that children may be taller or shorter than their parents since height inheritance is polygenic.

Adult Height Prediction

2) Another simple method is to double the height achieved by the child by age 2 for a boy, or age 18 months for a girl

- Birth length doubles by 3.5 years, and triples by 12 years

- The formula estimating average height of normal children aged 2 - 10 years was, height (cm) = age (yr) x 6.5 + 76 (cm)

- When this method proved unreliable, especially for girls, Roche refined the equation based on the results of the Fels Longitudinal study

- The new linear equations were more accurate:

  Males: 22.7 (in)plus 1.37 times height at 2 years.

  Females: 25.0 (in) plus 1.17 times height at 2 years.

Adult Height Prediction

B) Growth Charts

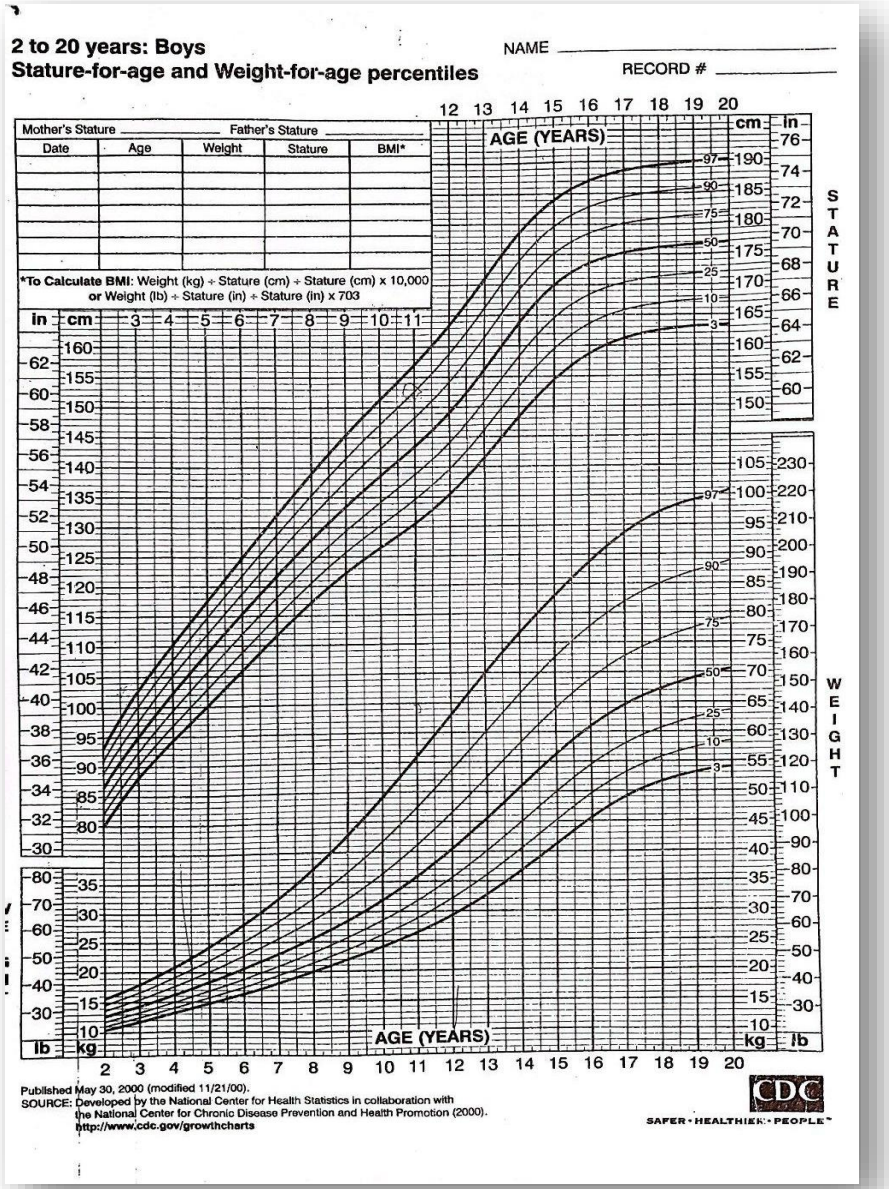
- The most popular charts are the WHO Charts for infants and children ages 0 to 2 and CDC Charts for children above 2.
- CDC Growth Charts of the United States are good sources of information to evaluate the growth situation of a child.

- There are 16 charts that contain data that can be used to compare the growth of a child over time.

- Measurements such as height, weight, and head circumference of a child can be compared to the expected values based on data from these growth charts of children of the same age and sex.

- In general, children maintain a fairly constant growth curve, which is why these charts can be used to predict the adult height of a child to a certain extent.

Adult Height Prediction



Adult Height Prediction

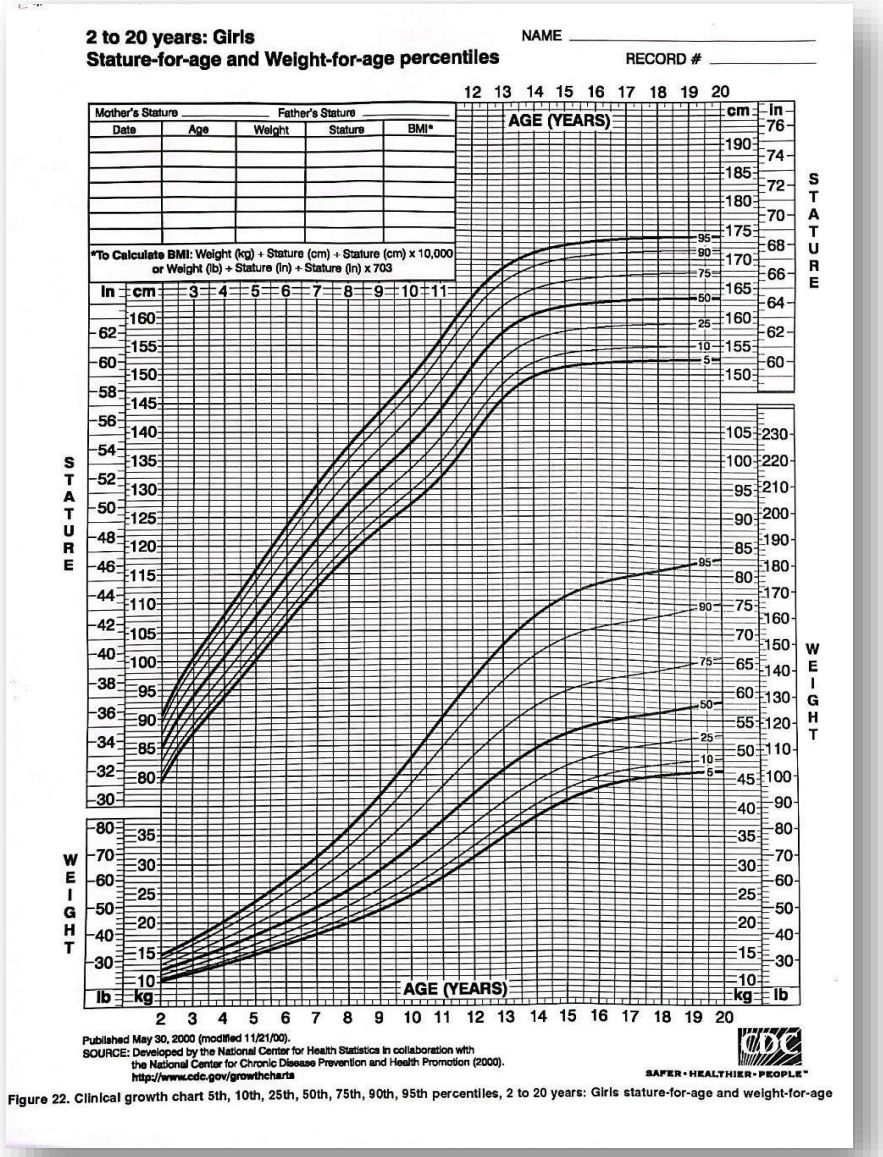


Figure 22. Clinical growth chart 5th, 10th, 25th, 50th, 75th, 90th, 95th percentiles, 2 to 20 years: Girls stature-for-age and weight-for-age

Adult Height Prediction

C) The Khamis-Roche method

- It was developed in 1994 by Dr. Harry Khamis and Dr. Alex Roche.
- The Khamis-Roche method is the most accurate method without the use of Bone age for AHP.
- A simple mathematical equation using parent height, current child height, and current child weight.
- For boys, the margin of error is 2.1 inches, and for girls, the margin is 1.7 inches.
- Most applicable to Caucasian children between the ages of 4 and 9 who are free from any growth-related condition or disease.
- So, it may be less accurate for kids of other ethnicities.

Adult Height Prediction

D) Bone age – skeletal maturity prediction

- Maturity of a child's skeletal system estimated by using a BA study.
- Single X-ray of the left wrist, hand, and fingers.
- Very small amount of radiation compared to standard atlas.
- Bone age is measured in years.
- Growth plates darker than the rest of the skeleton on the X-ray image.
- They look different at each age.
- The fusions are complete in ages 12-16 for girls and 14-19 for boys.
- Observing the difference between a child's bone age and chronological age may point to a growth problem, but it is not the rule. Some kids with perfect health can have a disparity in skeletal and chronological age.

Adult Height Prediction

- The control of bone age is done to assess the tempo of the maturing process of a child's skeleton.
- This allows doctors to diagnose conditions that delay or accelerate physical growth.
- Using the skeletal age, physicians may predict the following:
  - How long the child will be still growing
  - A child's final height
  - The start of puberty

Adult Height Prediction

- Bone age can be used to predict height and is considered more accurate than the other methods listed below.
- One such method is the Greulich-Pyle method that involves left hand and wrist radiographs to measure bone age.
- This method compares the radiograph of the patient to that of the nearest standard radiograph in the Greulich-Pyle atlas.
- It is possible to predict height based on the percentage of height growth remaining at a given bone age.
- The atlas were obtained between 1931 and 1942 from Caucasian children.
- Which may limit how accurately the Greulich-Pyle method can be used for current children.

Adult Height Prediction

- Seven most important methods for adult height prediction (AHP) based on bone age (BA).

- A new generation of methods for BA assessment has appeared approximately every twenty years, and each new BA method has led to a new generation of AHP methods.

- The first generation AHP model was formulated by Bayley (Bayley 1946) and was based on Todd's method for the determination of BA.

- Together with Pinneau, Bayley revised her AHP method in 1952 using the Greulich-Pyle (GP) atlas, thus completing the famous Bayley Pinneau (BP) method.

- GP is the most common BA rating method used today, and the BP method is still widely used all over the world.

Adult Height Prediction

Table 1: The four generations of bone age methods and the seven methods for adult height prediction.

Bone age Generations		Bone age methods	Adult height prediction methods	Bone age used in AHP
1	1946-59	Todd / Greulich-Pyle	Bayley-Pinneau (1946/52) RWT (1975)	Todd/GP GP bone-specific
2	1962-83	Tanner Whitehouse, TW1, TW2, TW3	TW Mark I (1975) TW Mark II (1983) TW3 (2001)	TW2 TW2 SMS
3	1987-93	Fels	RWT/Khamis (1993)	Fels
4	2008-	BoneXpert	BoneXpert (2009)	BoneXpert

Adult Height Prediction

- The Second Generation – Tanner In Europe, an alternative to the American GP/BP system was developed over four decades by Tanner and co-workers.

- The first description of the Tanner-Whitehouse (TW) skeletal maturity assessment system appeared in 1962.

- It was based on twenty bones.

- The operator assigns maturity stages A, B, .., I to each bone, and the TW system assigns a score to each stage, from which a summed maturity score (SMS) is formed ranging from 0 (immature) to 1000 (adult).

- The TW system then translates the SMS into a bone age based on data from a selected population.

Adult Height Prediction

- The Third Generation – Roche and collaborators developed the third BA method, the Fels method, in 1988.

- This method was based on the Fels longitudinal study which has recruited, on average, 18 children per year since 1933.

- This method is similar to the TW method, but involves more bones, more maturity features, and more advanced mathematics.

- Roche developed an AHP method called the RWT model (Roche-Wainer-Thissen).
- RWT method used combination of HT,BA,CA ,WT, midparental HT.

- In developing this model, Roche at first tried to use the bone ages of the hand, foot and knee, but he settled on using simply the median GP bone age of the hand

Adult Height Prediction

- The Fourth Generation – BoneXpert

- Finally, the BX AHP model, based on BX bone age, was presented in 2009 (Thodberg et al).

- The BX method, which constitutes the fourth generation of bone age methods, expresses the bone age based on the GP scale.

- Bone age can be automatically measured from a child's hand X-ray by the BoneXpert software.

- BoneXpert delivers precise and standardised readings, thus overcoming the problem of considerable reader variability of manual ratings.

Adult Height Prediction

- The seven AHP models all use current height, age, BA and gender to predict adult height.

- They differ mainly in the following three aspects:

  1) The type of BA, i.e, the weight assigned to different bones

  2) The reliability of the BA rating

  3) The population used for the estimation of the model and for its validation, e.g., the range of variation in height and BA delay and The mathematical model, how other information like parental height is incorporated.

Bayley Pinneau Method

TABLE 25.10 Prediction of Adult Stature

	FRACTION OF ADULT HEIGHT ATTAINED AT EACH BONE AGE[a]					
	GIRLS			BOYS		
Bone Age (yr-mo)	Retarded	Average	Advanced	Retarded	Average	Advanced
6-0	0.733	0.720		0.680		
6-3	0.742	0.729		0.690		
6-6	0.751	0.738		0.700		
6-9	0.763	0.751		0.709		
7-0	0.770	0.757	0.712	0.718	0.695	0.670
7-3	0.779	0.765	0.722	0.728	0.702	0.676
7-6	0.788	0.772	0.732	0.738	0.709	0.683
7-9	0.797	0.782	0.742	0.747	0.716	0.689
8-0	0.804	0.790	0.750	0.756	0.723	0.696
8-3	0.813	0.801	0.760	0.765	0.731	0.703
8-6	0.823	0.810	0.771	0.773	0.739	0.709
8-9	0.836	0.821	0.784	0.779	0.746	0.715
9-0	0.841	0.827	0.790	0.786	0.752	0.720
9-3	0.851	0.836	0.800	0.794	0.761	0.728
9-6	0.858	0.844	0.809	0.800	0.769	0.734
9-9	0.866	0.853	0.819	0.807	0.777	0.741
10-0	0.874	0.862	0.828	0.812	0.784	0.747
10-3	0.884	0.874	0.841	0.816	0.791	0.753
10-6	0.896	0.884	0.856	0.819	0.795	0.758
10-9	0.907	0.896	0.870	0.821	0.800	0.763
11-0	0.918	0.906	0.883	0.823	0.804	0.767
11-3	0.922	0.910	0.887	0.827	0.812	0.776
11-6	0.926	0.914	0.891	0.832	0.818	0.786
11-9	0.929	0.918	0.897	0.839	0.827	0.800
12-0	0.932	0.922	0.901	0.845	0.834	0.809
12-3	0.942	0.932	0.913	0.852	0.843	0.818
12-6	0.949	0.941	0.924	0.860	0.853	0.828
12-9	0.957	0.950	0.935	0.869	0.863	0.839
13-0	0.964	0.958	0.945	0.880	0.876	0.850
13-3	0.971	0.967	0.955		0.890	0.863
13-6	0.977	0.974	0.963		0.902	0.875
13-9	0.981	0.978	0.968		0.914	0.890
14-0	0.983	0.980	0.972		0.927	0.905
14-3	0.986	0.983	0.977		0.938	0.918
14-6	0.989	0.986	0.980		0.948	0.930
14-9	0.992	0.988	0.983		0.958	0.943
15-0	0.994	0.990	0.986		0.968	0.958
15-3	0.995	0.991	0.988		0.973	0.967
15-6	0.996	0.993	0.990		0.976	0.971

Bayley Pinneau Method

TABLE 25.10 Prediction of Adult Stature—cont'd

	FRACTION OF ADULT HEIGHT ATTAINED AT EACH BONE AGE[a]					
	GIRLS			BOYS		
Bone Age (yr-mo)	Retarded	Average	Advanced	Retarded	Average	Advanced
15-9	0.997	0.994	0.992		0.980	0.976
16-0	0.998	0.996	0.993		0.982	0.980
16-3	0.999	0.996	0.994		0.985	0.983
16-6	0.999	0.997	0.995		0.987	0.985
16-9	0.9995	0.998	0.997		0.989	0.988
17-0	1.00	0.999	0.998		0.991	0.990
17-3					0.993	
17-6		0.9995	0.9995		0.994	
17-9					0.995	
18-0		1.00			0.996	
18-3					0.998	
18-6					1.00	

[a]The column headed "Retarded" is used when bone age is >1 year below chronologic age; the column headed "Advanced" is used when bone age is >1 year greater than chronologic age.

Table derived from Post EM, Richman RA. A condensed table for predicting adult stature. *J Pediatr.* 1981;989:440–442 based on the data of Bayley and Pinneau.[1062] Predicted final height is calculated by dividing the current height by the fraction of adult height achieved determined from the table.

Adult Height Prediction

- How to get taller?

- Many people are not satisfied with their height.
- Is it possible to increase height after puberty at all?
- It is impossible to increase bone length after the closure of growth plates. It means that a human cannot grow taller.
- We can observe slight daily variations in height for most adults.
- The cause of these changes lies in spinal disc compression throughout the day.
- Daily activities impact the disc cartilage, which results in their height reduction.
- We are tallest just after night and shortest at the end of a long, active day.
- You may encounter myths about some techniques that will allow you to grow.

THANK YOU FOR YOUR ATTENTION

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