Encyclopedia of Human Development

Physical Development and Growth

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Differences in physical growth are apparent from everyday observations of people around us. We differ in terms of height, weight, the relative length of our body proportions, and fitness. We also differ in our abilities to move and perform physical skills and tasks. These differences provide valuable insights into our maturation, overall development, and health. As such, the study of physical growth and development is central to child development, medicine, education, and a host of other disciplines. It is also a subject of personal interest to all people in possession of a body.

Stages of Physical Growth

The general pattern of physical growth is similar for all individuals. There can be considerable variations, however, in terms of the rate and timing of growth and the size attained. Chronological age provides an obvious point of reference for observing and recording growth. Its significance should not be overstated, though; biological events and processes follow their own schedule. As it is sometimes said, biology does not celebrate birthdays!

Table 1 Stages of Human Growth

Stage	*Age/Growth Event*
Prenatal Growth	
Ovum Period	First 2 weeks after fertilization Cell division and increasing complexity
Embryo Period	Weeks 2 through 8 Steady growth; differentiation of cells into tissues, organ and systems
Fetus Period	Weeks 9 through 40 Rapid growth in size and mass; changes in body proportions; development of function in tissues, organs and systems
Postnatal Growth	
Infancy	Birth to end of weaning (about 24–36 months)
Early Childhood	Weaning to about seven years of age
Later Childhood	Seven years of age to puberty
Adolescence	Puberty to sexual and physical maturation, at about 20 years of age
Adulthood	20 years of age to end of menopause (for women)
Senescence	Menopause to death

Table 1 offers a brief overview of the different stages of human physical growth and the ages and events that often relate to them. Of course, any model of stages of development is necessarily somewhat arbitrary. The one presented here provides one way of understanding the process of physical growth, from conception to death.

The clearest distinction in human growth is between prenatal and postnatal stages. For obvious reasons, studies of prenatal growth are far more difficult to carry out than postnatal studies. However, recent research has offered valuable information and a more complete picture of physical growth throughout the course of life.

Prenatal Growth

There are two common approaches for categorizing growth in the prenatal period, which comprises on average 9 months, or 40 weeks. One way is in terms of the development of the organism as an ovum, an embryo and a fetus. The other approach is the well-known trimester model in which the course of pregnancy is usefully divided into 3-month periods. Discussing prenatal development in terms of trimesters is useful in certain contexts, such as clinical settings with mothers. However, because it only crudely relates to actual biological events, its value is limited. For this reason, the following discussion will consider prenatal growth in terms of biological events, particularly the development of the ovum, the embryo, and the fetus.

The Ovum

Growth begins at the moment of conception with the fertilization of the ovum (the mother's egg) by the father's sperm. The period of the ovum comprises the first 2 weeks after fertilization. It is a process of self-duplication and multiplication from single cells into tens of thousands of new cells. As cell division takes place, the cluster of cells resembles a raspberry and then changes position to form a hollow disk. During the second week after fertilization, the disk implants itself in the wall of the uterus (or womb), and a number of cellular layers become differentiated, including one that develops into the embryo.

The Embryo

Beginning with the formation of the embryo during the second week, this period is characterized by quite rapid growth differentiation of cells. Cells become specialized and organized to form the different tissues, organs, and bodily systems. By the end of this period, at about week 8, the embryo has developed the basic physical and functional features of a human, and changes during subsequent weeks are mainly in the dimension of physical features and refinement of functions. No new anatomical features appear after the embryo period.

The multiplication of cells and the specialization or differentiation of these cells into different organs and tissues makes the early stages of life highly susceptible to growth pathologies due to either genetic abnormalities or harmful environmental conditions, such as mother's poor nutrition or disease.

The Fetus

By week 9, the process of differentiation and specialization into tissues, organs, and bodily systems is largely complete. Growth is rapid during this period, especially from week 20. In fact, 90% of body weight at birth is attained during this second half of pregnancy. As well as marked increases in size and weight, the fetus period is characterized by changes to the body proportions. The embryo has an extremely large head in relation to the rest of the body, but as the fetus develops, the back and limbs grow rapidly in relation to the head, and the fetus takes a form much more recognizably human.

Importantly, from the perspective of the individual's survival after birth, the development of several bodily systems like blood circulation, breathing, and digestion occurs, preparing the fetus for the transition to life outside of the mother's uterus.

Postnatal Growth—The Growth Curve

The introduction of what has become known as the growth curve dates back to 18th-century France. Count Philibert Gueneau de Montbeillard measured the height of his son every 6 months from birth to 18 years of age, and these measurements were reported by his friend and celebrated scientist, George-Louie Leclerc de Buffon. These measurements were significant because they represented a new and valuable approach to measuring physical growth. Before this advance, the most common method for assessing growth was cross-sectional study, in which an individual is measured once. There is an inherent limitation of this approach because it can tell us nothing about individual development from 1 year to the next. It is precisely information about variability and changes in rates of growth that is most useful to both clinicians, wishing to compare an individual's rate to standards, and researchers, studying the relationship between early influences and later physical growth. A difficulty with the original measurements of Montbeillard's son was that they were recorded using antiquated French units. It was not until an American, Richard Scammon, converted these measurements into modern metric units in the early part of the 20th century that the information was made widely available in the form of a chart.

Growth charts are now staple elements of the study of physical growth. Despite the technological advances made in recent years, Montbeillard's measurements were remarkably accurate and reveal distinct phases of growth that continue to be valid today. Scammon's chart described the height achieved by the boy at all ages between birth and 18. This is called a *distance curve* because it reflects the child's progression toward maturity. Distance curves reveal some important facts about physical growth. There is obviously dramatic growth throughout the first 18 years of life, with a difference in height gains between boys and girls occurring around the early teen years. However, this is nonlinear: the individual does not increase the same amount of height each year, and there are periods of relatively large growth and others of relatively little growth. Although the distance curve can give a hint of these different stages of growth, these stages are far from clear. What is needed to show the differences in rates of growth over time is a *velocity curve*. An idealized velocity curve is shown in Figure 1.

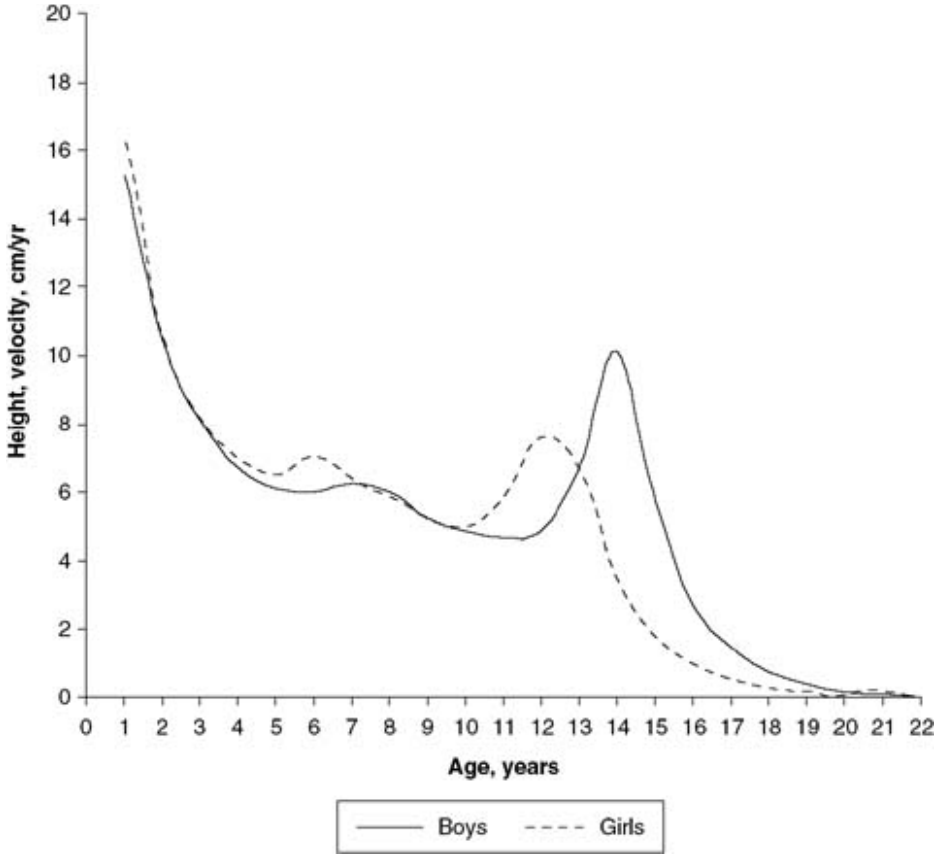

Figure 1 Idealized Mean Velocity Growth Curves for Boys and Girls

Immediately, it is possible to see that physical growth takes place through quite distinct phases. It is also possible to identify two spurts, the first occurring at about 6 to 8 years of age and the second, longer one, beginning at about 10 years for girls and 12 years for boys. Using the evident changes in the rate of growth as a starting point, it is possible to divide postnatal growth into a series of phases, with each phase characterized by distinct growth events and processes.

Phases of Postnatal Growth and Development

Although all human experience has the same basic pattern of growth, there are significant differences in individual rates and timing of growth during the life span. This is not just a point of academic interest. A school teacher of a class of 12-year-old girls or 14-year-old boys may be confronted with students of vastly different degrees of physical maturity, including relatively immature children and mature individuals who are almost adults.

Infancy

Infancy begins with birth and ends when the infant changes from lactation to eating solid food. The age of this development varies between different societies, and this variation is exacerbated by the trend in industrialized countries to reduce or eliminate the period of breast-feeding. In more traditional societies, which would seem to offer a more reliable indication, weaning normally ends at about 2 or 3 years.

The first months of postnatal life, called the *neonatal period*, is a time of transition from

the womb to the outside environment. The infancy phase is a period of rapid growth in most physical dimensions and bodily systems. Although there is a clear increase in the distance of growth, this period is characterized by a steep decrease in velocity. In many respects, this growth is a continuation of the fetus growth pattern. Alongside increases in height and weight during the first years, changes also occur in body proportions. Particularly noticeable is the relatively large head during infancy, which represents 25% of the total body length and is almost 70% of its eventual adult size. In the first year, the head accounts for 20% of body length, and by adulthood, it accounts for just 12%, with the legs taking 50% of total stature.

Table 2 Ages at Which Movement Skills Are Achieved

Age Range (months)	*Motor Milestone*
0.7–4.0	Head held erect
0.7–5.0	Turns from side to back
1.0–5.0	Sits upright with support
4.0–8.0	Unilateral reaching
5.0–9.0	Sits alone unsupported
5.0–12.0	Pulls up to stand position
7.0–12.0	Walks with assistance
9.0–16.0	Stands alone
9.0–17.0	Walks alone

Infancy is associated with the development of the musculoskeletal frame and the nervous system, especially the brain, which grows more rapidly during infancy than any other tissue or organ of the body. This development facilitates a host of cognitive and movement achievements. Most early movement is characterized by reflex actions, which are broadly defined as involuntary actions triggered by a range of external stimuli.

The period from 12 to 24 months is a time for the infant to practice and master many of the actions initiated during the first year and to add new ones. Although the rate of acquisition of skills varies according to each individual, the sequence of skills is quite predictable and seems to transcend social, cultural, and ethnic boundaries. Findings from research during the 1930s and 1940s established the creation of “motor milestones.” These are basic to skilled performance as each skill is a landmark in an infant's movement development (see Table 2).

Early Childhood

Following the deceleration of growth during infancy, the years between 3 and 7 witness a period of relatively rapid physical growth. It has often been noted that a characteristic feature of early childhood growth is its predictability, and a common pattern seems to be shared by all healthy children. In fact, this predictability has been used to good effect in clinical and epidemiological settings, to help detect ill health, by assessing deviations from normal growth.

Although children of this age have been weaned, they remain dependent on adult support, mainly because of their still developing cognitive and movement capabilities. Early childhood is a time for developing mastery in basic movement skills and for testing oneself physically in different environments. Movement activities can be viewed

from various perspectives, but most are based on the categories of stability (or balance), locomotion (or traveling), and manipulation (or control) because these are found in all ages. One further classification is into fine motor and gross motor activities. Fine motor activities involve movements that require precision and dexterity, usually regulating the use of hands and eyes together. Movement patterns in this category include writing, drawing, cutting, pasting, and the manipulation of small objects and instruments. Gross motor activities involve the whole body or major segments. Often referred to as *fundamental motor skills*, they include such skills as running, jumping, twisting, turning, hopping, throwing, and kicking (see Table 3).

Later Childhood

The transition from early to later childhood is sometimes marked by an increase in growth velocity, called the midgrowth spurt. During the subsequent phase, which occurs between about 7 years of age and the onset of puberty, the rate of growth declines. The rate of growth during later childhood, in terms of height and weight, as well as body tissues and systems, is the slowest since birth. Differences in size between boys and girls are insignificant during both early and later childhood phases. However, an extremely important difference does appear at the end of later childhood, as girls enter puberty some time before boys. Girls' later childhood period ends at about 10 years of age; for boys, it is at about 12 years.

The period between 7 years and puberty is sometimes referred to as the *skill-hungry years*. Occurring between the periods of rapid growth in early childhood and adolescence, it represents a time of relative stability, during which children can extend their physical competence in different contexts. Having already established fundamental movement skills, children now develop their skills in new and challenging situations. They do this by refining, combining, and elaborating on their fundamental movement skills to perform more specialized, often more socially stereotypical actions, such as sports, dance, and games.

Table 3 Movement Skills in Early Childhood

Age	*Fine Skills*	*Gross Skills*
3 years	Picks up blocks	Stands on one foot
	Places shapes in holes	Walks backwards and sideways
	Turns the pages of a book	Jumps down from a step
	Paints at an easel	Kicks a large ball with force
4 years	Holds a pencil in an adult way	Pedals a tricycle
	Copies a square accurately	Hops on the spot and along
	Brings thumbs into opposition	Bounces a large ball
	Colors inside lines	Runs smoothly
5 years	Uses a knife and fork competently	Can touch toes when upright
	Threads a needle and sews	Jumps for height up to 30 cm
	Copies a triangle accurately	Dances rhythmically to music
	Does jigsaws with joining pieces	Walks downstairs with alternating feet
6 years	Ties own shoe laces	Skips with alternate feet
	Writes first and last names	Catches a ball with consistency

Holds a pencil with finger tips	Kicks a football up to 6 meters
Builds a straight tower of cubes	Throws a ball using wrists and fingers

Adolescence

Progression to adolescence is marked by a rapid acceleration in the velocity of growth of almost all body parts, although different parts of the body reach their peak rate of growth at different times. The duration of the period of acceleration, called the *adolescent growth spurt*, is usually greater in boys than in girls, although there is a great deal of individual difference. On completion of the adolescent growth spurt, men are, on average, taller and heavier than women. This seems to be common to all societies and ethnicities. The difference in final height and weight between males and females appears to be attributable to two main factors: the delay of the onset of puberty in boys and the greater intensity of the growth spurt in boys. The consequences of these, and other factors, is the adult stature of women averages about 90% of the stature of men.

Adolescence is the time when sexual maturation takes places, with visible signs such as a sudden increase in the density of pubic hair, and, in the case of girls, the development of the breast bud. Other significant events during adolescence include the production of viable sperm in boys and egg cells in girls, although these do not signal full sexual maturity. This is particularly the case in girls, for whom the first menstrual period, or menarche, is often followed by a period of sterility. On average, girls are not fertile until about 14 years of age or later, and a further 4 years are often needed before full sexual maturity is reached. The adolescent stage of growth is also the phase during which secondary sexual characteristics develop, such as changes to the external genitalia and differences in body size and body composition.

Adulthood and Senescence

The transition from adolescence to adulthood is primarily characterized by two events: the end of increases in height and full reproductive maturity. The course of physical growth during adulthood is relatively uneventful. Regular, weight-bearing physical activity will increase muscle mass; regular, low-intensity exercise will generally decrease body fat, whereas overeating will increase the amount of body fat. Generally speaking, however, the adult stage is characterized by its stability.

Western men and women from high socioeconomic groups tend to reach adult height at about 20 years and 18 years, respectively. Other groups tend to achieve adult height a little later, with the cultural differences presumably attributable to degrees of access to quality nutrition and health care. Those suffering from undernutrition may continue to grow for some years later, although they rarely reach the final stature of their healthier, often wealthier peers.

Aging, or senescence, is characterized by a process of decline in an individual's ability to reproduce and adapt to stress. There is a large degree of variability in the onset and nature of senescence. Although some traits, such as loss of skin elasticity, reduced movement capacity, and female menopause, or the end of menstruation at about 45 and 55 years, are common to most societies; others, such as cardiovascular disease, brittle bones, and arthritis, are more likely to be culture-specific consequences of Western lifestyles.

Measuring Growth

The evolution of the study of physical growth has been briefly discussed in the previous section. Essentially, there are two basic kinds of studies: cross-sectional and longitudinal. In cross-sectional studies, individuals are measured once. Typically a large number of individuals are measured at each chronological age, and the average measurements are calculated. Longitudinal studies involve repeated measurements of individuals over a number of years. Compared with cross-sectional studies, longitudinal research is very time consuming and usually necessitates a restricted sample size. This partially accounts for the relative variety of longitudinal studies of growth.

Recent advances have made available a great number of tools for measuring physical growth. Some of these tools involve the use of complex specialist equipment; however, most growth studies continue to use methods that are quite easy to understand and replicate.

The potential measures that could be made of the human body are almost infinite, but certain techniques have been established, and some of these are listed and described in Table 4.

Regulation of Physical Growth

The process of physical growth is a complex one, influenced by genetic, hormonal, and environmental factors. Genes offer a potential range for achieving physical size and shape, and the environment partly determines the eventual growth within that range.

Genes do not influence growth directly. They produce proteins that regulate a genetically inherited pattern of growth, mediated by the endocrine and neurological systems. In essence, the endocrine system—the system of glands under neural control responsible for the release of regulatory chemicals—provides the biochemical environment in which genes act. For example, the adolescent growth spurt cannot occur without the release of sufficient quantities of growth and sex-specific hormones into the blood. Harmful environmental insults cause a reduction in the release of growth hormone and other hormones, resulting in reduced growth. To this extent, the endocrine system acts as an intermediary between the action of the genes and the influence of the environment.

Although genes and the endocrine system have significant influence on the regulation of physical growth, environmental factors—those that are nongenetic and external to the organism—can also account for some of the differences between individuals. Unfavorable environmental conditions, such as nutrition, negative psychological and social experiences, and pollutants, can start to affect growth adversely from shortly after the moment of conception, and continue throughout the life span.

The effects of harmful environmental conditions on growth seem to be dependent on the severity and duration of the problem, as well as the age at which it occurs. Young children are particularly vulnerable to such insults. However, there is some evidence to suggest that, when the insult is removed and adequate nutrition is available, retardation of growth is usually followed by a period of catch-up growth, during which the individual rapidly returns to or approaches a normal rate of growth. A useful analogy for this period of catch-up was provided by the British geneticist, C. H. Waddington, who compared physical growth to the movement of a ball down a valley floor. He suggested that an insult may knock the ball away from a central pathway, and the velocity of its

movement will then reduce. Once the insult is corrected, though, the ball returns toward the valley floor at an increased speed, upon which normal velocity recommences. If the insult is not corrected, perhaps because of continued poor diet, the individual may resume growth at a relatively slower rate, and skeletal maturation may be delayed, extending the period of growth. Scholars disagree regarding the long-term effects of harmful environmental conditions during infancy and childhood, but there is some evidence to suggest that severe difficulties can result in negative lasting effects. In most cases, however, it seems to be the case that growth merely slows down in response to harmful conditions, and waits for better times.

Table 4 Common Measurements of Individual Growth

Stature	Standing	Floor to top of head (no shoes)
	Lying	Feet to top of head while lying on back
	Sitting	Sitting surface/buttocks to top of head
Breadth	Shoulders	Outside of left to outside of right upper arm
	Hips	Outside of left to outside of right hip, at waist
	Knees	Widest aspect
	Elbows	Widest aspect
Circumferences	Upper arm	Midway between shoulder and elbow, with arm hanging loosely to side
	Calf	“Belly” calf, standing
	Head	Forehead level
Skinfold	Triceps muscle	Double-fold of skin at back of upper arm
	Subscapular	Fold beneath shoulder blade
	Suprailiac	Fold above waist

Because environmental factors rarely operate in isolation, it can be difficult to quantify the precise relationship between specific influences and physical growth. Nevertheless, there are certain factors that have well-documented effects on physical growth, including nutrition, social and environmental status, psychological stress, and pollutants.

Nutrition

Adequate nutrition is of fundamental importance to physical growth and development. A reduction in the rate of growth is one of the first responses to restricted food intake, and in countries where food is persistently limited, growth delays occur, and children tend to be shorter and lighter than in countries with adequate food supplies. In fact, so strongly associated are growth and nutrition that measurement of physical growth is one of the most widely used indices of nutritional status in children.

Although the effects of poor nutrition can be experienced at all stages of development, including during the prenatal growth, infancy and early childhood represent the periods during which the developing child's system is unusually sensitive to malnutrition. This seems to be, in part, because the first years of life witness the most rapid growth. International studies suggest that about half of all deaths during the first 5 years result from the effects of poor nutrition and the associated inability to fight infectious diseases.

Adolescence is another period when individuals are especially vulnerable to the harmful effects of malnutrition. Nutritional needs are greater during this period than at any other time of life, and although the rate of proportionate growth is somewhat less than during the early years, it persists for much longer. As is well known, adolescence is a time when young people experiment with food choices, and inappropriate choices can have profound and longlasting effects. Conditions such as anorexia nervosa (a disorder characterized by an abnormal fear of becoming obese) and bulimia nervosa (an eating disorder, in which binge eating is often followed by feelings of guilt and fasting) are especially common among adolescent girls and can seriously threaten both health and physical growth. Aside from retarding an individual's rate of growth, inappropriate diet can also have harmful effects on skeletal development, and insufficient food intake has been associated with the development of osteoporosis, or brittle bones, in women.

Social and Economic Status

Children from poorer families are generally shorter and lighter than their peers in higher -income families. They also consume less food. The timing of growth, rather than growth itself, seems to be most affected by social and economic factors; for example, the onset of puberty occurs earlier in individuals from wealthier groups than those from poorer groups. Studies of preschoolers have reported differences in height, weight, skin-fold thickness, and musculature in favor of children from high social and economic status families. By the time they reach adulthood, much of the difference is reduced or even cancelled. Social and economic factors are most evident among males. In fact, most environmental influences seem to affect males more strongly than females. The reasons for such differences are unclear.

Psychological Stress

There is considerable evidence that extreme stress can slow physical growth and development. The mechanisms involved in such effects are unclear, although stress may negatively affect the secretion of growth hormones. A cluster of factors like maternal care, social isolation, parental substance abuse, and sexual abuse are linked to psychological and emotional ill health. Recent research has also indicated that some children are genetically predisposed to stress and respond to it in an extreme and prolonged manner that results in restricted growth.

Pollutants

Physical growth is sensitive to several pollutants, including lead, air pollution, certain organic compounds, and tobacco smoke. Of course, pollutants are somewhat unavoidable in the modern world, but levels of pollution vary considerably, and so its effects will be different among different groups. To take only one example, smoking by the mother during pregnancy is well known to affect both birth weight and an infant's subsequent growth. It also seems that living in a home with smoking parents is related to reduced height and weight throughout infancy and childhood. The insult to weight seems to be corrected as the individual moves toward adolescence; the deficit in height is probably never made up.

Conclusion

Physical growth is essentially a biological process, but it is affected and constrained by

the environments in which it takes place. The interaction of biological and environmental factors accounts for the great variation in growth that is evident among both individuals and whole populations. It also influences the development of other physical characteristics, such as movement skills.

Growth is an important, if often overlooked, aspect of human development. Its centrality is most evident during the periods of infancy and childhood, when physical changes make available a wide range of new behaviors and experiences. Physical growth and development affect the way individuals perceive themselves and how others perceive them. Growth also gives visible clues of an individual's stage of overall development and of that individual's state of health and well-being. As such, it warrants attention by all of those interested in human development.

- physical development and growth
- embryo
- ova
- fetuses
- nutrition
- endocrine system
- infancy

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